DOCUMENT RESUME

ED 091 214 SE 017 786

AUTHOR Bates, Gary C.
TITLE A Search for Subscales in the "Science Process Inventory."
PUB DATE 17 Apr 74
NOTE 74p.; Paper presented at the annual meeting of the National Association for Research in Science Teaching (47th, Chicago, Illinois, April 1974)

EDRS PRICE MF-$0.75 HC-$3.15 PLUS POSTAGE
DESCRIPTORS Educational Research; *Evaluation; Factor Structure; *Measurement Instruments; *Physics; *Science Education; *Scientific Enterprise; Secondary School Students
IDENTIFIERS Research Reports; *Science Process Inventory

ABSTRACT

Reported are the findings of a research project designed to identify subscales in the "Science Process Inventory" (SPI) developed by Welch in the 1960's to assess student knowledge about the nature and processes of science. Form D of the instrument was used with a random subsample of 435 students who were included in the Harvard Project Physics summative evaluation which used a national random sample of physics classes in the United States. Factor analysis of 43 items selected on the basis of moderate difficulty level and demonstrated discriminating power did suggest five factor scales of three to four items each. These "protoscales" are considered to hold promise for developing useful scales of 10-20 similar items. Also discussed in this report are several issues related to the construction of a multidimensional instrument for measuring student knowledge about the nature and processes of science. Appendices are also included with the report. (Author/PEB)

ED 091214

U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

A Search for Subscales in the Science Process Inventory

Gary C. Bates
Harvard University

~~Appendices upon request.~~

324 Longfellow Hall
Harvard University
Cambridge, Ma. 02138

Presented at:
National Association for
Research in Science Teaching
Chicago, April 17, 1974

SE 017 786

ABSTRACT: A Search for Subscales in the Science Process Inventory

Gary C. Bates
Harvard University

National Association for Research
in Science Teaching
Chicago, April 17, 1974

The Science Process Inventory (SPI) is one of several instruments developed during the 1960's to assess student knowledge about the nature and processes of science. SPI (form D) has a single scale comprised of 135 statements to which students "agree" or "disagree". This instrument has been used in a number of research studies.

A single test score does not provide educators and curriculum developers much specific information for modifying instruction. It was hoped that a number of independent subscales might be found among the 135 test items. This study used a random subsample of 435 students who were included in the Harvard Project Physics summative evaluation which used a national random sample of physics classes in the United States.

Because of the very low correlations between the items, factor analysis of the total test has not provided interpretable factors. Efforts to group the items into subscales based on the original conceptual organization of the test items also failed to produce reliable scales. However, a factor analysis of 43 items selected on the basis of moderate difficulty level and demonstrated discriminating power did suggest five factor scales of 3-4 items each. These "protoscales" hold promise for developing useful scales of 10-20 similar items.

Several issues related to the construction of a multidimensional instrument to measure student knowledge about the nature and processes of science are also discussed. These include: 1) the philosophical bias of the test, 2) criteria for levels of difficulty and discriminating power, 3) appropriate response format, 4) need for a theoretical model, 5) need for development of a series of instruments, and 6) criteria for assuring a multidimensional instrument will be used by practitioners as well as researchers.

Introduction

The Science Process Inventory (SPI) is one of several instruments developed during the 1960's to assess student knowledge about the nature and processes of science.[1] Since "knowledge" is prerequisite to higher levels of the Bloom Taxonomy, reliable measures of student knowledge in this area should provide valuable information to both teachers and curriculum developers. However, the single scale score for all of the 135 items in SPI is a gross measure which provides little specific guidance for modifying instruction.

This study explored the possibility of using items from SPI to describe student knowledge about several dimensions of the nature and processes of science. In general, divisions such as "Classification" or "Theories" did not produce usable subscales; however, five interpretable "protoscales" each containing 3-5 items with reliabilities of 0.4-0.5 were identified. These protoscales suggest that relevant dimensions will reflect different philosophies of science such as the "Realist" or "Instrumentalist"; beliefs such as "Nature-Understandable" or "Science-Tentative"; and specific concepts such as "Measurement-Approximate". In addition to encouraging continued efforts to develop a multidimensional instrument, this study also suggests several guidelines for future work.

Some Background Information on SPI

The Science Process Inventory (form D) contains 135 statements to which students are asked to "agree" or "disagree", e.g.

25. A theory in science may be modified in light of new evidence. (A) D

These statements were drawn from several prominent books on the history and philosophy of science.[2] Only those concepts which occured in a majority of the books surveyed were included in the instrument. A copy of form D of the Science Process Inventory has been included in Appendix A.

Norms for the 150 item form C were obtained using a sample of 1283 senior high school students (grades 10-12) in two Wisconsin high schools. The results as reported by Welch[3] are shown in Table 1. The differences between grades 11 and 12 are significant ($p < .05$).

TABLE 1 -- Norm Data for SPI (form C)

grade	N	rel.	std. error	mean	std. dev.	range
12	444	.80	4.6	108.8	10.4	77-132
11	403	.79	4.8	106.8	10.5	70-132
10	436	.78	4.8	107.0	10.4	70-134
	1283			107.5	10.4	

Welch also used SPI to compare high school students, high school teachers, and a group of scientists (see Table 2).[4] The significant differences ($p < .05$) among these groups was inter-

as an indication of the validity of the instrument.

TABLE 2 -- Comparison of three groups on SPI

group	N	mean	std dev
High School Students	1283	107.5	10.3
High School Teachers	16	129.4	6.7
Scientists	19	135.0	4.7

A shorter form of SPI was used in the Harvard Project Physics (HPP) summative evaluation (1967-68) which included a national random sample of physics classes.[5] Statistics for a random subsample of approximately 1/4 of the students in the HPP study are reported in Table 3. The high mean

TABLE 3 -- Norm Data for SPI (form D) (HPP data)

N	rel.	std. error	mean	std. dev.
435	.76	4.0	107.0	8.14

of this sample reflects the increased homogeneity of the universe of students who elect to take physics as compared to all students enrolled in high school. The physics students in the HPP sample had a mean IQ of 117 (Henmon-Nelson),[6] and SPI has been shown to be correlated with IQ $r \sim .61$.[7] A (2x3) multivariate analysis of variance (course x IQ) showed a significant IQ effect ($p < .01$),

but no course or interaction effects between the HPP experimental and the control classes.[8]

SPI has also been used in several other studies including the evaluation of Physical Science for the Non-Scientist,[9] and Aikenhead has used items from SPI to investigate alternate methods for assessing student knowledge about the nature and processes of science.[10]

Some General Comments about SPI

There are several general questions relating to tests which measure student knowledge about the nature and processes of science. Three areas of concern in this study include 1) the philosophical bias of the instrument, 2) criteria for the level of difficulty and discriminating power of items, and 3) the choice of paper and pencil response format.

The first of these concerns is the tension which exists within SPI between two philosophies of science -- the Realist and the Instrumentalist. A Realist assumes that an external REALITY actually exists and that the pursuit of science has helped mankind make successively closer approximations to TRUTH. This philosophical perspective was characteristic of the physical models of Newtonian Classical physics which, at the time, appeared to have resolved the major riddles of the universe. The "correct" response to several SPI items reflects the Realistic philosophy, e.g.

69. Those people who carry on the practice of science assume that: matter is an idea, not reality. A (D)

The development of atomic and electromagnetic theory in the late 19th and 20th Centuries brought the Realistic perspective into question. The physical models which were proposed to explain phenomena such as polarization and propagation of electromagnetic waves became increasingly absurd and were ultimately replaced by mathematical equations. No longer was it necessary to provide a physical model to explain how phenomena occurred -- an internally consistant set of equations which accounted for the phenomena would suffice. Further, the work of Thomas Kuhn[11] demonstrated that the major scientific revolutions have resulted in fundamental restructuring of "Reality". The immobile earth became a fleeting planet. Phlogiston evaporated. Time and space have been combined and made relative.

This new perspective is reflected in the Instrumentalist[12] philosophy which has abandoned the search for "Truth" and is content with a science which is internally consistant for the phenomena as scientists currently perceive them. A student who holds the sophisticated Instrumentalist philosophy will be penalized in responding to many of the items in SPI.

One of the protoscales identified in this study also suggests that some students hold a naively "Literal" interpretation of

scientific models. For example, they tend to agree with statements such as

35. [The Bohr model of the atom] is a scaled-up picture of what scientists have seen in their microscopes. A (D)

It is important that instruments intended to measure student knowledge about the nature and processes of science explicitly recognize and hopefully measure differences such as those among the scientific Literalist, Realist, and Instrumentalist.

The second concern is that most of the items in SPI are very easy (see Table 4). The average item difficulty is approx-

---

Insert Table 4 about here

---

imately 0.8 with 45% of the items higher than 0.90.

Figure 1 shows the standard deviation (σ) of the SPI items as a function of their difficulty. This is the binomial distribution (solid curve) for which the variance decreases very rapidly as the probability of the event approaches 0 or 1.

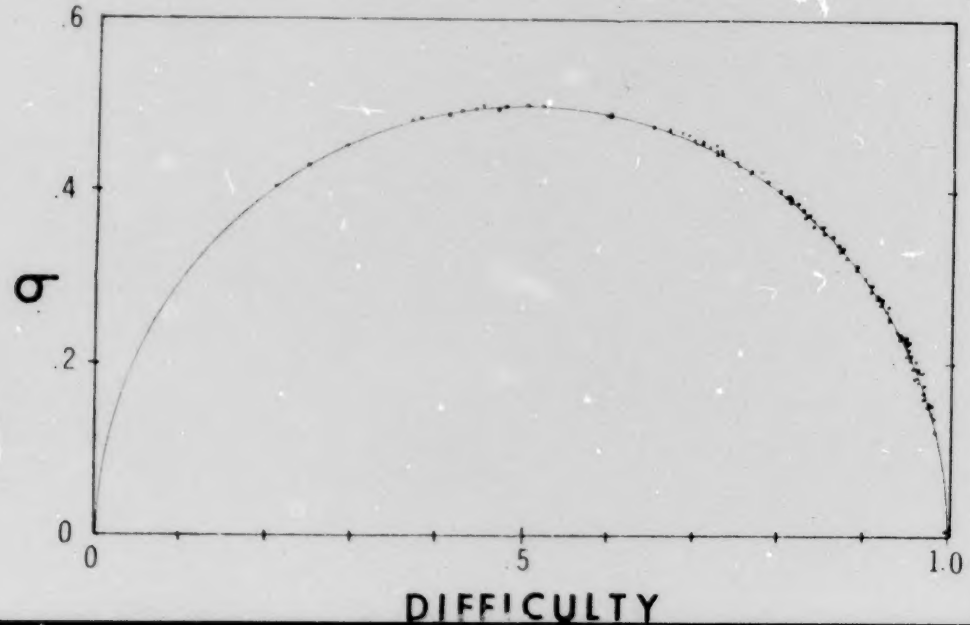


TABLE 4 -- Mean (Difficulty) and Standard Deviation for SPI items*

Item	Mean	SD	Item	Mean	SD
100 17 ASUM PST EXPRENCE VAR(1)	0.840	0.367	216133 WK 1 PRM-ANS OTHR VAR(35)	0.968	0.177
100 22 SCTS MK NO ASUMPT VAR(2)	0.964	0.185	220 88 HOT MOR PRECIS 84 VAR(36)	0.942	0.234
100 27 ASUM NT ACT PRV T VAR(3)	0.410	0.492	220 93 OBS MOR BIO TN PY VAR(37)	0.953	0.212
110 69 MATTER IDEA NT RL VAR(4)	0.893	0.309	220 98 15 IN-EXACT TRUTH VAR(38)	0.781	0.413
110 72 TIME CN B MEASURE VAR(5)	0.812	0.391	220103 MSUR #-CNT B WRNG VAR(39)	0.956	0.205
110 76 TIME NT REAL VAR(6)	0.838	0.369	220108 THERMTR-MSUR DEVI VAR(40)	0.976	0.154
110 73 SPACE N EXIST VAR(7)	0.922	0.268	220113 MSUR WTH N ERROR VAR(41)	0.959	0.197
110104 REAL WORLD EXISTS VAR(8)	0.851	0.356	220118 QUANT LES TN QUAL VAR(42)	0.346	0.361
120 74 MIND UNDRSTD NTUR VAR(9)	0.786	0.410	230 52 CLASIF-COMON FCTR VAR(43)	0.921	0.270
120 75 NATUR NVR UNDRSTD VAR(10)	0.473	0.499	230 56 COL ROCKS IS SCI VAR(44)	0.418	0.493
120 77 PBMS 2 CMPLX 2 EX VAR(11)	0.694	0.461	230 61 CLASIF P INHERENT VAR(45)	0.251	0.434
130 12 ORDER IN UNIVERSE VAR(12)	0.891	0.311	230 78 CLASIF GD ORGANIZ VAR(46)	0.972	0.16
130 63 PRESNT CLU 2 PAST VAR(13)	0.828	0.377	230 83 GRP OBS-PART SCI VAR(47)	0.971	0.168
130109 NATUR CHNG SUDDEN VAR(14)	0.875	0.330	240 26 EXPIMT-COND 4 OBS VAR(48)	0.982	0.1
130114 NATUR IS CONSISTA VAR(15)	0.898	0.303	240 30 EXPMT PRV LWS NAT VAR(49)	0.454	0.49
130119 EXPMTS CONSISTANT VAR(16)	0.595	0.491	240 39 EXPMT TEST HYPOTH VAR(50)	0.961	0.19
130126 GRAVITY EVERYWHER VAR(17)	0.865	0.341	240 43 CONTROL IN EXPMT VAR(51)	0.733	0.443
130127 NATURE PREDICTABL VAR(18)	0.880	0.325	240 48 EXPMT N AGREE-WNG VAR(52)	0.969	0.173
140 20 A IMPLIES B VAR(19)	0.938	0.240	240 57 EXPMT ALLOW CNTRL VAR(53)	0.669	0.470
140 66 OCCUR N HV CAUSES VAR(20)	0.911	0.285	250 3 SCTS DIFRNT OPINS VAR(54)	0.950	0.218
140 67 ALL EFCTS HV CAUS VAR(21)	0.943	0.231	250 6 SCT SHUD PUBLISH VAR(55)	0.932	0.252
140 68 AB SAME TIME-CAUS VAR(22)	0.810	0.392	250 11 SCTS ACPT EXPT NO VAR(56)	0.930	0.255
140 70 EVNTS HV DISC CAS VAR(23)	0.809	0.393	250 16 SCTS SHARE FINDGS VAR(57)	0.859	0.348
140 71 DA-DB--A CAUSES B VAR(24)	0.681	0.466	250 21 RSCH DESB IN JRNL VAR(58)	0.950	0.218
140123 SAME CAUS-S EFECT VAR(25)	0.872	0.334	250122 SCTS SEARCH LITUR VAR(59)	0.953	0.212
211 10 GOOD SCT ASK RT Q VAR(26)	0.780	0.415	261 62 INDUCTION VAR(60)	0.379	0.485
211 29 OBS 2 ANS SPECF Q VAR(27)	0.840	0.367	262 40 HYP-SEA CNTS SALT VAR(61)	0.595	0.491
212 5 OBS INFL PST EXPC VAR(28)	0.723	0.448	262 58 HYP IS A "HUNCH" VAR(62)	0.750	0.433
212 47 SUNRIS DIF 2 PEOP VAR(29)	0.964	0.185	262 80 HYP-MAY BE WRONG VAR(63)	0.968	0.177
213 38 INSTRMTS AID SENS VAR(30)	0.969	0.173	262 85 HYP IS SCI FACT VAR(64)	0.916	0.278
214 2 SCT KEEPS RECORDS VAR(31)	0.997	0.057	262105 HYP-SUG NEW EXPMT VAR(65)	0.867	0.339
215 42 ACUR OBS WASTE TM VAR(32)	0.969	0.173	262115 HYP-FRM IMAGINATN VAR(66)	0.817	0.387
216 1 UNEXPTD IMPT 2 SC VAR(33)	0.977	0.149	263 89 DED-PART FM GENRL VAR(67)	0.831	0.374
216112 SM DISCOV R LUCK VAR(34)	0.887	0.317	263 99 DED-SWAN SYLLOGSM VAR(68)	0.921	0.270

TABLE 4-- (continued)

Item	Mean	SD
264 8 THY-TEST PREDICTN VAR(69)	0.671	0.470
264 94 PREDCTN GOAL THYS VAR(70)	0.890	0.313
264 95 THY EXPLAIN FACTS VAR(71)	0.911	0.285
265 79 THY&HYP-EM COMPAR VAR(72)	0.930	0.255
265 82 IF FAIL-NT S MTHD VAR(73)	0.955	0.208
265 84 SUCCESS-IF S MTHD VAR(74)	0.924	0.265
265107 SCI INV-DEF PROCD VAR(75)	0.718	0.450
265121 ONLY 1 SCI MTHD VAR(76)	0.874	0.332
265124 SCI MTHD-BITE ANS VAR(77)	0.963	0.189
265128 TRIAL&ER-SUCC SCI VAR(78)	0.801	0.400
265130 ONLY 1 SOLN 2 PRM VAR(79)	0.909	0.287
265135 MNY MTD 2 SLV PRM VAR(80)	0.951	0.215
265 37 NO ERS IF ACT SCI VAR(81)	0.958	0.201
310 91 12 IN. IS APPROX VAR(82)	0.707	0.455
310125 SCI IS STATISTICL VAR(83)	0.648	0.477
310132 "DEGRE OF ESTMAT" VAR(84)	0.932	0.252
320 19 SCI APRX 2 TRUTH VAR(85)	0.859	0.348
320 25 THY MAY B MODIFED VAR(86)	0.985	0.120
320 28 KNWL SCI IS FINAL VAR(87)	0.969	0.173
320106 SCI KNWL DVLPING VAR(88)	0.964	0.185
320111 LOF-UNCHNG TRUTH VAR(89)	0.366	0.482
320116 CRNT SCI-BST APRX VAR(90)	0.908	0.290
320120 SCI KNWL-TENTATIV VAR(91)	0.783	0.412
330 7 THY-N NEED TEST VAR(92)	0.976	0.154
330 18 THY-SUG NEW RELTN VAR(93)	0.971	0.168
330 50 HYP MOR SUPRT THY VAR(94)	0.726	0.446
330 53 THYS-MATH RELATNS VAR(95)	0.914	0.280
330 54 36 SNOFAL-SCI THY VAR(96)	0.804	0.397
330 64 MST NW THYS ACPTD VAR(97)	0.749	0.434
330100 "MTR-MOL" IS THY VAR(98)	0.806	0.396
330110 ACPT THY +-OVR N- VAR(99)	0.726	0.446
340 31 MODELS-PIC OF ATM VAR(100)	0.721	0.448
340 32 MODEL-HELP UNDERS VAR(101)	0.981	0.138
340 33 MODEL-CLRS OF ATM VAR(102)	0.846	0.361
340 34 MODEL-MAN MADE VAR(103)	0.914	0.280
340 35 MDL-SCALD UP PICT VAR(104)	0.768	0.422
340 36 MDLS MAY B MODIF VAR(105)	0.948	0.222
340 59 MDLS-EXACT REALTY VAR(106)	0.947	0.225
340 81 MDLS R DEFECTIVE VAR(107)	0.828	0.377
350 13 LAW-DSCR OBSRVTNS VAR(108)	0.874	0.332
350 14 LAW IS PERMANENT VAR(109)	0.475	0.499
350 23 LAW-NTR NT DISOBY VAR(110)	0.948	0.222
350 24 LAW-NEVER CHANGE VAR(111)	0.919	0.273
350 45 LAW-DESCR NT PERS VAR(112)	0.806	0.396
350 49 LAW-NTR MUST DO VAR(113)	0.807	0.395
410 46 TASK SCI 2 EM THY VAR(114)	0.872	0.334
410 51 RSCH-THY NT APPLY VAR(115)	0.501	0.500
410117 RSCH SHD HV APPLY VAR(116)	0.293	0.455
410129 SCI-IMP LIVG COND VAR(117)	0.674	0.469
420 4 OBS NOW LES IMPRT VAR(118)	0.959	0.197
420 15 SCI PREJUDICE OBS VAR(119)	0.927	0.260
420 60 SCI-FCTS NT OPIN VAR(120)	0.951	0.215
420131 ACPT THY-OPIN,FCT VAR(121)	0.830	0.376
430 41 SCI STS&END W FCT VAR(122)	0.441	0.496
430 44 ASUM-OPIN NT FACT VAR(123)	0.695	0.460
430 55 PUB RES-ACPT WT Q VAR(124)	0.979	0.144
430 87 SCI SKEPT-N OWN W VAR(125)	0.835	0.371
430 92 SCI RELY OTSD ATH VAR(126)	0.820	0.384
430 97 Q NTS THY GVTY-NS VAR(127)	0.947	0.225
430102 NOW THYS-OPP,PROP VAR(128)	0.958	0.201
440 65 SCI N TRY CREAT L VAR(129)	0.763	0.425
450 90 SCI DISP OWN HYP VAR(130)	0.848	0.359
450134 EXPR SHD B REPEAT VAR(131)	0.976	0.154
460 9 SMPLR HYP ACCEPTD VAR(132)	0.425	0.494
460 86 SCI 2 MOR CMPLX VAR(133)	0.520	0.500
460 96 CHOS MOR CMPLX TH VAR(134)	0.955	0.208
460101 SCI PREF SMPL EXP VAR(135)	0.768	0.422

*A sample of 617 students was used here. This included students of 21 "experienced" teachers who had taught HPP in previous years and were not randomly selected. The possible sample bias is not important for this portion of the analysis.

If an instrument contains only very easy items, the distribution of scores will be skewed to the right making it difficult to discriminate among the "better" students. Likewise, a test composed of very hard items fails to discriminate among the "less able" students.

For a mastery test, a high difficulty level is desirable because the purpose of the instrument is to demonstrate that students exceed some minimum level of competence. There is no need to discriminate among students who pass the test. However, discrimination is paramount to an instrument intended to describe differences among students. It is also desirable that the test accomplish its purpose in as parsimonious manner as possible. The norm data for form C of SPI (Table 1) show a range of 70-134. Nearly half of the items in the test provide little information about differences among students.

For maximum discrimination, the mean item difficulty should be around 0.5. Whether the difficulty level of all items should be 0.5 or represent a range of difficulties with a mean near 0.5 depends upon the nature of the test. If the test is assumed to contain independent items which measure a variety of concepts, then it is best to include items with uniform difficulty near 0.5 which provides maximum positive and negative variation on each item. However, if the scale is intended to measure a single concept, then the items will be intercorrelated and a range of difficulties should be included.

Some might argue against choosing a mean difficulty near 0.5 because the "guessing" level for an "agree"-"disagree" response format is also 0.5. A chimpanzee marking responses at random would receive an "average score" on the test. However, contrary to the classroom behavior of some students, the data do not suggest that many students respond to the items in SPI as would their hypothetical primate counterpart. If guessing were a serious problem, then it would be reflected in very low discriminating power for the items with difficulty levels near 0.5. If fact, many of the most discriminating items in the subscales are those with modest difficulty levels of 0.4 to 0.6 (see Appendix B).

The fact that a large portion of the SPI items are very easy for high school students suggests that they already have an acceptable understanding of many concepts about the nature and processes of science. Perhaps many of these less difficult items could be included in a simpler instrument appropriate for upper grade school and early junior high.[14]

The question of guessing could also be made moot by a change in the response format. If a four point scale (AA A D DD) with a confidence scale (L M H) were used, guessing would be minimized and students would have more latitude in responding.[15]

These concerns preclude generating a multidimensional instrument directly from the existing items in SPI; however, the following search for subscales was valuable in identifying possible dimensions of such an instrument.

Approach to the Analysis

Aikenhead factor analyzed SPI in total, but found factors which could not be readily interpreted.[16] However, his analysis did establish that SPI does not contain a strong general factor.

The difficulty in factor analyzing the total test arises from the very low intercorrelations among the items. A portion of the correlation matrix has been reproduced in Table 5.

Insert Table 5 about here

Cronback[17] notes that for items found in psychometric tests, the correlation among items is ordinarily below 0.3. Although several of the items correlate 0.1 to 0.3, the relationships are too weak to allow meaningful factor analysis of the total 135 items.

Relatively low phi correlations (ϕ_{ij}) are to be expected because the maximum possible correlation between two dichotomous variables depends upon their relative difficulty and the homogeneity of the items as indicated by their tetrachoric correlation (r_{tet}) (see Figure 2).[18] If two homogeneous items ($r_{tet} = 1.00$) have identical levels of difficulty ($p_i = p_j$), then they can be perfectly correlated. However, as their levels of difficulty diverge, the maximum possible correlation between them rapidly decreases.

TABLE 5 -- Portion of Correlation Matrix for SPI items*

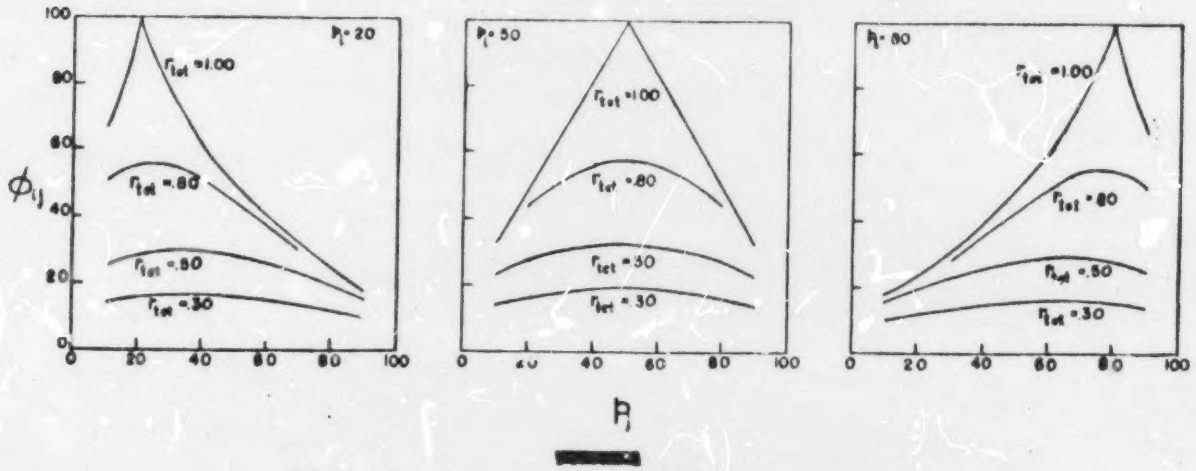
CORRELATION COEFFICIENTS

VARIABLE DESCRIPTION	NAME	VAR (1)	VAR (2)	VAR (3)	VAR (4)	VAR (5)	VAR (6)	VAR (7)
100 17 ASUM PST EXPRENCE	VAR(1)	1.000						
100 22 SCTS MK NO ASUMPT	VAR(2)	0.035	1.000					
100 27 ASUM NT ACT PRV T	VAR(3)	0.050	0.125**	1.000				
110 69 MATTER IDEA NT RL	VAR(4)	0.006	-0.010	0.022	1.000			
110 72 TIME CN B MEASURE	VAR(5)	0.016	-0.003	0.013	0.048	1.000		
110 76 TIME NT REAL	VAR(6)	0.047	0.034	0.018	0.204***	0.295***	1.000	
110 73 SPACE N EXIST	VAR(7)	0.038	0.042	0.008	0.076	0.170***	0.233***	1.000
110104 REAL WORLD EXISTS	VAR(8)	0.102*	-0.031	-0.003	0.017	-0.027	0.050	0.048
120 74 MIND UNDRSTD NTUR	VAR(9)	0.030	-0.036	-0.031	-0.053	0.184***	0.071	0.055
120 75 NATUR NVR UNDRSTD	VAR(10)	0.034	-0.010	-0.005	-0.019	0.140***	0.073	-0.016
120 77 PBMS 2 CMPLX 2 EX	VAR(11)	0.045	0.024	0.039	-0.025	0.130**	0.051	0.056
130 12 ORDER IN UNIVERSE	VAR(12)	0.075	0.158***	0.090*	-0.070	0.032	-0.040	-0.043
130 63 PRESNT CLU 2 PAST	VAR(13)	0.105**	0.005	0.048	0.093*	0.012	-0.014	-0.036
130109 NATUR CHNG SUDDEN	VAR(14)	-0.005	0.033	0.066	0.107**	0.044	0.020	0.037
130114 NATUR IS CONSISTA	VAR(15)	0.071	0.022	0.053	-0.013	-0.012	-0.047	-0.038
130119 EXPMTS CONSISTANT	VAR(16)	0.026	0.019	-0.023	-0.019	-0.034	-0.040	-0.043
130126 GRAVITY EVERYWHER	VAR(17)	0.035	0.052	0.020	-0.060	0.041	-0.044	-0.044

*The appropriate correlation for dichotomous data is the phi coefficient. However, for dichotomous variables scored '0' or '1', the phi coefficient is equivalent to the Pearson Product-Moment Correlation. Therefore, it was possible to use the DATATEXT Program to calculate the correlations between the items.

A sample of 617 students was used in this calculation. Students of 21 "experienced" teachers who had taught HPP in previous years and were not randomly selected are included. The possible sample bias is not important for this portion of the analysis.

As the items become less homogeneous, the effect of item difficulty b comes less pronounced, but the maximum correlation is severely suppressed.



Relation of ϕ_{ij} to p_i and p_j for Several Levels of Correlation.

Figure 2

Given these constraints, two efforts were made to examine the SPI items for possible subscales. The first was to hypothesize a set of subscales based on Welch's classification of the items. This did not result in useful subscales. The second effort was to factor analyze a sample of items which met certain criteria of difficulty and discriminating power. This factor analysis produced five promising "protoscales".

The 13 Hypothesized Subscales

An effort to increase homogeneity among items was made by grouping items which appeared to be related into 13 hypothesized subscales. These subscales are similar to the original organization suggested by Welch[19] (see Table 6) with many of the

---

Insert Table 6 about here

---

subdivisions combined. Fourteen items were not included in any of the subscales. A list of the items and statistical data for each subscale is provided in Appendix B. A summary of these data is presented in Table 7.

Insert Table 7 about here

Given the homogeneity of the student sample and the reduced number of items in each subscale, we did not expect them to have particularly high reliabilities. Indeed, the reliabilities range from 0.12 to 0.50, too low for the scales to be useful or to significantly increase their reliability by simply adding more items. More sophisticated procedures are required.

The first effort to improve the hypothesized subscales was to select only the "best" items. The resultant sub-subscales contained only 3-4 items, but it was hoped that they would provide a strong nucleus of items around which more could be written. If a scale of three items has a reliability of 0.4,

TABLE 6 -- Conceptual Organization of SPI

Code	Concept	Item # (form B=150 items)	Item # (form D=135 items)
100	I. Assumptions	58,59,60	(17),22,27
110	A. Reality	47,65,69,70,74	304,69,72,73,76
120	B. Intelligibility	71,72,73,75	74,75,X,77
130	C. Consistency	48,49,50,51,53,54,55,56,57	109,114,119,X,127,128,X,63,12
140	D. Causality	5,52,61,62,63,64,66,67,68	20,123,66,67,68,X,70,71,X
200	II. Activities		
210	A. Observations		
211	1. Selected	3,7	10,29
212	2. Infl. past experien.	2,11	5,74
213	3. Using instruments	8	38
214	4. Recording	1	2
215	5. Describing accurat.	9	42
216	6. Unexpected	10,140,147	1,112,133
220	B. Measurement	18,19,20,21,22,23,24	88,93,98,103,108,113,118
230	C. Classification	12,13,14,15,16,17	52,56,61,78,X,83
240	D. Experimentation	31,32,33,34,35,36,37,38	26,X,X,30,39,43,48,57
250	E. Communication	25,26,27,28,29,30	122,6,11,3,16,21
260	F. Mental Processes		
261	1. Induction	39,40,46	62,X,X
262	2. Formulate hypotheses	79,81,82,88,90,102	58,80,85,105,115,40
263	3. Deduction	43,45	89,99
264	4. Form. theories, pred	44,48,91	94,95,8
265	5. Many techniques	41,42,134,139,142,143,145,146,148	79,84,82,107,121,124,128,130,135
300	III. Nature of Outcomes		
310	A. Probability	111,118,119,120,126	91,125,X,132,37
320	B. Tentativeness	87,114,115,116,117,123,125	25,106,111,116,120,19,28
330	C. Theories	78,80,85,89,92,94,104,105,107	53,7,100,110,X,18,50,54,64
340	D. Models	96,97,98,99,100,101,106,108,109	31,32,33,34,35,36,59,81,X
350	E. Laws	77,86,93,95,103,122,124	49,X,13,23,45,14,24
400	IV. Ethics and Goals		
410	A. Goals & motivation	128,129,141,144,130	46,51,117,129,X
420	B. Objectivity	4,6,132,150	15,4,60,131
430	C. Anti-authority, skept.	127,131,135,136,137,138,76	41,55,87,92,97,102,44
440	D. Amorality	133	65
450	E. Repeatability	83,149	90,134
460	F. Parsimony	110,112,113,121	86,96,101,9

TABLE 7 -- The 13 Hypothesized SPI Subscales

	Name	# items	mean	Std Dev	Std Error	KR Rel
1	Universe: Orderly and Understandable	10	6.93	1.66	1.356	0.333
2	Assumptions of Science	8	6.26	1.15	1.028	0.206
3	Causality	7	5.78	1.13	0.949	0.291
4	Science is Tentative	15	12.64	1.47	1.256	0.267
5	Scientific Knowledge-Public and Objective	9	7.32	1.22	1.060	0.248
6	Scientific Methods	12	10.54	1.31	1.046	0.360
7	Experimentation	9	7.43	1.08	1.019	0.116
8	Measurement	9	7.91	1.20	0.903	0.431
9	Observation	9	8.11	0.90	0.824	0.166
10	Hypotheses	7	5.29	1.23	1.045	0.281
11	Theories	13	10.77	1.46	1.284	0.229
12	Models	8	6.57	1.37	0.969	0.503
13	Laws	6	4.54	1.09	0.944	0.246

then a scale containing ten similar items can be expected to have a reliability approaching 0.7. The selection criteria for items was based on the following analysis.

The internal reliability of an instrument can be found using the general formula:

$$r_{tt} = \frac{n}{n-1}\left[1 - \frac{\sum_i V_i}{V_t}\right]$$

Where n is the number of items in the test, V_t is the variance of the test scores, and V_i is the variance of item score after weighting.

If students respond to the items of the test at random, then the total observed variance for the test will be the sum of the item variances, the quantity in the bracket becomes zero, and the reliability of the test will be zero. However, if individual students consistently score above or below the mean for the items of the test, then the observed variance of test scores will be greater than the sum of the item variances and the reliability of the test will be $0 < r_{rr} < 1$.

Since the item variance (V_i) is fixed for a given sample, an effort was made to increase the test variance (V_t) by selecting items which were both discriminating and of moderate difficulty. The discriminating power was the point biserial correlation between the item and the subscale. A range of items with modest

levels of difficulty was desired because the subscales were assumed to be homogeneous. The following criteria were used to select items:

1) $r_{tt} \geq 0.4$

2) $0.2 \leq \text{Diff} \leq 0.8$

Six of the subscales contained three or more items which met these criteria. They have been reported in Table 8.

Insert Table 8 about here

This procedure resulted in groups of highly discriminating items; however, the reliabilities for all except two of the sub-subscales are disasterously low. If subscales do exist, they are not the obvious catagories such as "Laws", "Hypotheses", etc.

Factor Analysis of Selected SPI Items

Thus far we have shown that if dimensions of knowing about the nature and processes of science exist, they are considerably more subtle than might have been expected. We have also identified a pool of 43 items which have modest difficulty and demonstrated discrimination. While these items need not represent all of the "useful" items in SPI, they do provide a reasonable sample for using factor analytic techniques to discover possible relations.

TABLE 8 -- Selected Items from Some Subscales

	Subscale	Dif	Dis	#	Mean	σ	KR#20
1-(2)	Universe: Orderly & Understandable			4	2.32	1.18	0.464
	3 (120- 74) MIND UNDRST NTUR	.75	.59				
	4 (120- 75) NATUR NVR UNDRSTD	.43	.72				
	5 (120- 77) PBMS 2 CMPLX 2 EX	.66	.65				
	8 (130-119) EXPMTS CONSISTANT	.49	.53				
3-(2)	Causality			3	2.22	0.77	0.067
	4 (140- 68) AB SAME TIME--CAUS	.80	.51				
	5 (140- 70) EVNTS HV DISC CAUS	.73	.68				
	6 (140- 71) DA-DB--A CAUSES B	.69	.58				
7-(2)	Experimentation			3	1.79	0.85	-.001
	3 (240- 30) EXPMT PRV LWS NAT	.53	.58				
	6 (240- 43) CONTROL IN EXPMT	.65	.57				
	8 (240- 57) EXPMT ALLOW CONTROL	.61	.59				
10-(2)	Hypotheses			3	2.05	0.89	0.261
	2 (330- 50) HYP MOR SUPRT THY	.64	.65				
	3 (262- 58) HYP IS A "HUNCH"	.70	.68				
	7 (262-115) HYP-FROM IMAGINATN	.71	.58				
12-(2)	Models			3	2.08	0.91	0.396
	1 (340- 31) MODELS-PIC OF ATOM	.60	.74				
	5 (340- 35) MDL-SCALD UP PICT	.67	.71				
	8 (340- 81) MDLS R DEFECTIVE	.81	.56				
13-(2)	Laws			3	1.94	0.81	0.126
	1 (350- 13) LAW-DSCB OBSRVTNS	.79	.55				
	2 (350- 14) LAW IS PERMANENT	.41	.66				
	6 (350- 49) LAW-NTR MUST DO	.74	.59				

The results of the factor analysis are reported in Table 9. Items with factor loading greater than 0.4 have been circled.

Insert Table 9 about here

Five of the seven factors can be readily interpreted:

Factor I - Nature-Understandable
II - Scientific Literalist
III - Measurement-Approximate
IV - } Mixtures of misconceptions
V - }
VI - Science Tentative
VII - Scientific Methods

Items which loaded greater than 0.4 on only a single factor were grouped into new subscales which were examined by item analysis. The selected items have been marked with an asterisk in Table 9. The results are reported in Table 10.

Insert Table 10 about here

These factor-subscales are encouraging. The homogeneous scales such as I (Nature-Understandable), IIb (Literalist), and III (Measurement-Approximate) have reliabilities around 0.4-0.5 for only 3-4 items. These can be expanded to strong scales by adding 6-7 similar items. The Factor-subscales VI (Science-Tentative) and VII (Scientific Methods) are more heterogeneous and would require 15-20 additional items to produce sufficiently reliable scales. Factor-subscale II (Literalist) requires further study with the addition of other examples of literal interpretation.

TABLE 9 -- Factor Analysis of Selected SPI Items

code	item	1	2	3	4	5	6	7	communality
120 74	MISC UNPRSTG NTUR	0.531 *	0.013	0.032	0.003	-0.023	0.021	0.129	0.300
120 75	NATUR RVA UNPRSTG	0.708 *	-0.054	-0.038	-0.106	-0.009	0.116	0.058	0.534
120 77	PBMS 2 CMPLX 2 EX	0.563 *	-0.137	0.052	-0.010	0.064	-0.136	-0.126	0.378
130119	EXPMTS CONSISTANT	0.260	-0.208	-0.045	0.165	-0.255	-0.230	0.042	0.263
130127	NATURE PREDICTABL	0.083	-0.402	-0.081	0.181	0.046	-0.095	0.279	0.294
140 66	OCCUR N HV CAUSES	0.287	-0.036	0.054	0.175	0.257	0.176	0.147	0.236
140 68	AS SAME TIME-CAUS	0.259	-0.107	-0.167	-0.209	0.026	0.252	-0.218	0.323
140 70	EVNTS HV DISC CAS	0.412	0.049	-0.017	0.257	-0.029	0.079	0.313	0.344
140 71	DA-DB--A CAUSES B	-0.112	0.158	0.042	-0.065	0.033	0.124	0.573 *	0.388
450 90	SCI DISP OWN EXP	0.007	0.055	0.057	0.183	-0.027	0.524 *	0.043	0.318
450101	SCI PREF SMPL EXP	0.047	-0.178	-0.012	-0.269	-0.018	-0.006	0.350 *	0.234
320120	SCI KNWL-TENTATIV	-0.073	0.054	0.055	-0.130	-0.130	0.464 *	0.101	0.273
250 6	SCI SHOD PUBLISH	-0.055	-0.250	-0.193	-0.315	0.020	0.271	0.217	0.321
430 41	SCI STS&LAD W FCT	0.068	0.410 *	0.024	-0.118	-0.167	0.148	0.187	0.271
430 44	ASUM-OPIN NT FACT	0.114	-0.103	-0.037	0.035	0.131	0.395 *	-0.075	0.212
420131	ACPT THY-OPIN.FCT	0.164	-0.155	-0.067	0.100	0.405	0.105	-0.171	0.270
265107	SCI INV-DEF PRCCD	0.159	0.124	0.171	-0.082	0.025	0.262	-0.267	0.217
265121	ONLY 1 SCI MTHD	-0.221	-0.120	-0.127	0.164	0.056	0.135	-0.131	0.148
265130	ONLY 1 SELN 2 PRV	-0.039	-0.450 *	0.105	-0.134	0.072	-0.137	0.111	0.286
240 30	EXPMT PRV LAS NAT	0.125	0.018	-0.069	0.177	0.312	0.257	-0.158	0.240
240 43	CONTROL IN EXPMT	0.025	-0.036	-0.001	-0.218	-0.358	0.071	-0.060	0.193
240 57	EXPMT ALLOW CNTRL	0.158	-0.023	-0.004	0.013	-0.034	0.077	0.548 *	0.332
310 91	12 IN. IS APPROX	-0.076	-0.093	0.710 *	-0.064	-0.143	0.074	0.064	0.553
220 98	15 IN-EXACT TRUTH	0.011	-0.169	0.711 *	0.002	-0.055	0.166	-0.074	0.570
220113	MSUR WTH N ERROR	0.152	0.100	0.455 *	-0.007	0.242	0.196	-0.079	0.347
212 5	OBS INFL PST EXPC	0.017	-0.355	0.016	0.124	-0.310	0.260	-0.056	0.186
211 23	OBS 2 ANS SPECF S	0.164	0.044	0.053	0.114	-0.180	-0.159	0.414 *	0.275
262 40	HYP-SEA CNTS SALI	0.149	-0.014	-0.035	0.321	0.164	0.096	-0.131	0.180
330 50	HYP MOR SUPRT THY	0.195	-0.052	0.036	-0.485	-0.063	0.074	-0.267	0.364
262 58	HYP IS A "HUNCH"	0.244	0.007	0.172	-0.390	-0.072	-0.021	0.017	0.247
262115	HYP-FOR IMAGINATN	0.259	-0.019	0.059	-0.100	-0.128	0.037	-0.058	0.195
264 8	THY-TEST PREDICTN	0.016	-0.033	0.207	0.223	-0.501	0.060	0.074	0.418
264 94	PREDCTN GOAL THYS	0.064	-0.174	0.094	0.492	-0.224	0.121	-0.050	0.353
340 31	MODELS-PIC OF ATM	0.185	-0.417 *	0.017	0.000	-0.129	0.274	-0.051	0.303
340 33	MODEL-CLAS OF ATM	0.152	-0.375	-0.036	0.003	0.240	0.045	-0.225	0.278
340 35	MDL-SCALD UP PICT	0.170	-0.563 *	-0.000	-0.034	-0.111	0.171	-0.144	0.409
340 36	MDLS MAY B MODIF	-0.081	-0.476 *	0.137	-0.037	-0.086	0.083	0.139	0.287
340 59	MDLS-EXACT REALTY	0.040	-0.437	0.274	0.119	0.135	0.288	-0.126	0.415
340 81	MDLS R DEFECTIVE	-0.023	-0.195	0.156	0.004	-0.071	0.440 *	0.101	0.272
350 13	LAW-DSCB OBSRVTNS	0.048	-0.040	0.299	-0.065	0.067	-0.100	0.215	0.158
350 14	LAW IS PERMANENT	-0.002	0.020	0.357	0.058	-0.075	-0.078	-0.340	0.259
350 23	LAW-NTR NT DISOBY	0.024	-0.048	0.321	-0.086	0.406	-0.144	0.079	0.305
350 49	LAW-NTR MUST DO	-0.061	-0.137	0.155	0.026	0.464	0.027	-0.057	0.266
	sums of squares	2.089	2.027	1.945	1.454	1.848	1.772	1.877	13.016

TABLE 10 -- Selected Items from SPI Factor Analysis

	Factor	Dif	Dis	#	Mean		KR#20
I	Nature-Understandable			3	1.84	1.01	0.535
	(120- 74) MIND UNDRST NTUR	.75	.64				
	(120- 75) NATUR NVR UNDRSTD	.43	.80				
	(120- 77) PBMS 2 CMPLX 2 EX	.66	.72				
II	Literalist			5	3.51	1.07	0.237
	(340- 31) MODELS-PIC OF ATM	.60	.62				
	(340- 35) MDL-SCALD UP PICT	.67	.64				
	(340- 36) MDLS MAY B MODIF	.87	.50				
	(430- 41) SCI STS&END W FCT	.49	.36				
	(265-130) ONLY 1 SOLN 2 PBM	.89	.38				
				3	2.08	0.91	0.396
	(340- 31) MODELS-PIC OF ATM	.60	.74				
	(340- 35) MDL-SCALD UP PICT	.67	.71				
	(340- 81) MDLS R DEFECTIVE	.81	.56				
III	Measurement-Approximate			3	2.39	0.86	0.578
	(310- 9.) 12 IN. IS APPROX	.67	.85				
	(220- 98) 15 IN-EXACT TRUTH	.79	.82				
	(220-113) MSUR WTH N ERROR	.93	.50				
VI	Science Tentative			4	2.95	0.99	0.318
	(430- 44) ASSUM-OPIN NT FACT	.62	.60				
	(340- 81) MDLS R DEFECTIVE	.81	.54				
	(450- 90) SCI DISP OWN HYP	.77	.62				
	(320-120) SCI KNWL-TENTATIV	.76	.53				
VII	Scientific Methods			4	2.68	1.07	0.341
	(211- 29) OBS 2 ANS SPECF Q	.81	.51				
	(240- 57) EXPMT ALLOW CNTRL	.61	.63				
	(140- 71) DA-DB--A CAUSES B	.69	.60				
	(460-101) SCI PREF SMPL EXP	.57	.58				

Conclusion

Although we have failed to find usable subscales in the Science Process Inventory, this effort has been most encouraging for the future development of a multidimensional instrument to measure student's knowledge about the nature and processes of science. There are also several guidelines for developing such an instrument.

1) Theoretical Model A theoretical model which identifies the important dimensions of knowing about the nature and processes of science must be developed. A model will provide the basis for both interpreting the scales and for selecting items. This study suggests that the dimensions will be subtle and that considerable theoretical and empirical effort will be needed to identify them.

2) Refinement of Scales The scales need to be quite well developed separately before techniques such as factor analysis will prove useful for "purifying" the total instrument.

3) Item Selection Items should meet criteria of difficulty and discriminating power similar to those suggested in the last section, i.e. mean difficulty ~ 0.5, discrimination > 0.4.

4) Response Format The "agree"-"disagree" format provides little latitude for student response. If the purpose of the instrument is to describe rather than evaluate student's knowledge about the nature and processes of science, then a four point scale (AA A D DD) with a confidence scale (L M H) may provide

more useful information. Alternate response formats surely need to be tested and evaluated during the development of a multidimensional instrument.

5) Test Series The fact that a large portion of the SPI items are very easy for high school students suggests that they already have an acceptable understanding of many concepts about the nature and processes of science. These less difficult items might be included in a simpler instrument appropriate for upper grade school and early junior high school.

6) Usefulness An instrument which is too cumbersome, esoteric, or long will not be of much interest to any but a few researchers. Although the amount of class time that can be allocated to testing is severely limited, it is reasonable to devote one class period to a regular testing program if the yield is rich enough. Thus, a multidimensional instrument should include some scales relating to the social aspects of science and an indication of student attitudes toward science.

This paper has demonstrated that the development of a multidimensional instrument to measure student knowledge about the nature and processes of science is feasible. What is needed at this time is a cooperative effort on the part of several science education researchers to advance the state of the art.

FOOTNOTES

1 - A number of these instruments are discussed by Glen S. Aikenhead, "The Measurement of High School Students' Knowledge About Science and Scientists", Science Education, 57(4) 539-549 (1973).

2-4 Welch, Wayne and Milton O. Pella, "The Development of an Instrument for Inventorying Knowledge of the Processes of Science", Journal of Research in Science Teaching, 5(1) 64-68 (1967).

5 - Welch, Wayne, "Review of the Research and Evaluation Program of Harvard Project Physics", Journal of Research in Science Teaching, 10(4) 365-378 (1973).

6 - Welch, Wayne, "Some Characteristics of High School Physics Students: circa 1968", Journal of Research in Science Teaching, 6(3) 242-247 (1969).

7 - Welch and Pella (1967).

8 - Welch, Wayne W., Herbert J. Walberg, and Fletcher G. Watson, "A Case Study in Curriculum Evaluation: Harvard Project Physics", University of Minnesota, Minneapolis, Minnesota, 1971, p172 (Unpublished mimeograph).

9 - Welch, Wayne, "Evaluation of the PSNS Course. I: Design and Implementation", and "Evaluation of the PSNS Course. II: Results", Journal of Research in Science Teaching, 9(2) 139-156 (1972). Also Tamir, P., "Understanding the Process of Science By Students Exposed to Differential Science Curricula In Isreal", Journal of Research in Science Teaching, 9(3) 239-245 (1972).

10 - Aikenhead, Glen S., "Course Evaluation: The Construction and Interpretation of Tests", Saskatchewan Journal of Educational Research and Development, 4, 45-53 (Fall, 1973). Also by Aikenhead, "Course Evaluation I: A New Methodology for Test Construction" and "Course Evaluation II: Interpretation of Student Performance on Evaluative Tests", Journal of Research in Science Teaching, (in press).

11 - Kuhn, Thomas, The Structure of Scientific Revolutions, Chicago: University of Chicago Press.

12 - Nagel, Ernest, The Structure of Science, Chapter 6, New York: Harcourt, Brace & World, Inc., 1961. R. M. Harre discusses Realism and Positivism in The Principles of Scientific Thought, Chicago: University of Chicago Press. A. H. Munby studied the teaching implications of the Realist and Instrumentalist philosophies in his thesis "The Provision Made for Selected Intellectual Consequences by Science Teaching: Derivation and Application of an Analytical Scheme", Unpublished doctors thesis, University of Toronto, 1973.

13 - Marshall, Jon Clark and Loyde W. Hales, Classroom Test Construction, Reading, Mass: Addison-Wesley, 1972, p224.

14 - The Test on Understanding Science (TOUS) has been adapted for junior high school and elementary grade levels. See Klopfer, L. E. and E. O. Carrier, "Test on Understanding Science: Form Jw", Pittsburg, Penn.: Learning Research and Development Centre, 1970.

15 - Several researchers have used a variety of response formats. In the Nature of Science Scale (NOSS) students may 1) agree, 2) disagree, or 3) indicate they are unsure, do not understand or feel neutral about an item. The Test on the Social Aspects of Science (TSAS) uses a five point scale from "strongly agree" to "strongly disagree". The Wisconsin Inventory of Science Processes (WISP) uses a three response format similar to NOSS to which students respont 1) accurate, 2) inaccurate, or 3) not understood. However, the scoring procedure combines the last two catagories and is equivalent to the scoring system used in SPI. The content of WISP and SPI are also essentially identical. The Test on Understanding Science (TOUS) uses a four-alternative multiple choice format. The Facts About Science Test (FAS) uses a three-alternative multiple choice format. These instruments are discussed in the Aikenhead article (footnote #1).

16 -Personal correspondence with Glen Aikenhead, November, 1973.

17 - Cronback, Lee. J., "Coefficient Alpha and the Internal Structure of Tests", Psychometrika, 16(3) 297-334 (1951).

18 - Cronback, 1951, p 325.

19 - Welch, Wayne W., "The Development of An Instrument for Inventorying Knowledge of the Processes of Science", Unpublished doctor's thesis. Madison, Wisconson: University of Wisconson, 1966 p79.

APPENDIX A

Science Process Inventory

Form D (Revised 1966)

Wayne W. Welch
University of Wisconsin

WELCH SCIENCE PROCESS INVENTORY

Form D (Revised 1966)

Wayne W. Welch
University of Wisconsin*

*Now at Harvard University, Cambridge, Mass.

PRINT YOUR NAME IN THE BOXES PROVIDED. THEN BLACKEN THE LETTER BOX BELOW WHICH MATCHES EACH LETTER OF YOUR NAME.

YOUR LAST NAME | YOUR FIRST NAME | MI

FORM OF THIS TEST IS: A 1 B 2 C 3 D 4

TEACHER ONLY: STUDENT ABSENT FOR PART: I II III IV

STUDENT NUMBER

BIRTH DATE MO/YEAR | SEX | GRADE

SCHOOL _____ CITY _____

INSTRUCTOR _____ GRADE _____ TEST _____

STANDARD ANSWER SHEET -C

DS 1120-C

OPTICAL SCANNING CORPORATION, FAIRLESS HILLS, PA.

WELCH SCIENCE PROCESS INVENTORY

Form D (Revised 1966)

Directions

The following statements are concerned with the activities, assumptions, products, and ethics of science. Read each statement carefully and then mark your answer on the answer sheet provided. BLACKEN SPACE ONE (1) on the answer sheet if you generally AGREE with the statement; BLACKEN SPACE TWO (2) if you generally DISAGREE.

Example:		A	D
1.	New York is a city.	1. ■	2 3 4 5
2.	Chicago is a mountain.	2. 1 ■	3 4 5

Do not mark spaces 3, 4, or 5. If you change your mind, erase the first mark completely. Make no stray marks; they may count against you.

Use a pencil to mark your answer sheet. DO NOT USE A PEN. Please supply information concerning name, school, birth date, etc., in the appropriate spaces on the answer sheet. Do not write in the test booklet.

Answer all statements. You will have 40 minutes which should give you sufficient time to finish all 135 statements. A scoring key has been established for the Inventory. Slightly more than half of the statements are keyed agree while the remainder are keyed disagree.

Note carefully the numbering sequence on the answer sheet.

DO NOT TURN THE PAGE UNTIL TOLD TO DO SO.

SCIENCE PROCESS INVENTORY

Blacken space 1 on your answer sheet if you generally AGREE with the statement; blacken space 2 if you generally DISAGREE.

		Agree	Dis-agree
1.	Surprising or unexpected observations have played an important role in the advance of science.	1	2
2.	The work of a scientist includes keeping a record of observations.	1	2
3.	Scientists have differences of opinion about scientific matters.	1	2
4.	Careful observation is less important in modern science since the development of new instruments like the electron microscope.	1	2
5.	The observations a person makes are influenced by his past experience.	1	2
6.	A scientist should make his findings available to the scientific community for independent confirmation.	1	2
7.	Theories are usually so well established, they do not require experimental testing.	1	2
8.	The essential test of a scientific theory is its use in predicting future events.	1	2
9.	If two different hypotheses fit the observed facts, the simpler is accepted.	1	2
10.	An essential characteristic of the scientist is the ability to ask the right questions.	1	2
11.	If a researcher accurately reports his experimental procedures, other researchers will accept the experimental conclusions without question.	1	2
12.	Scientists assume there is order in the universe.	1	2
13.	A law of nature, such as Ohm's Law, is a statement that describes what has been observed.	1	2
14.	Although a scientific hypothesis may have to be changed on the basis of new data, a physical law is permanent.	1	2
15.	A scientist wishes to make prejudiced observations of nature.	1	2
16.	Scientists should be unwilling to share their findings with other scientists.	1	2
17.	Assumptions in science are based on past experience.	1	2
18.	Theories suggest new relationships among facts.	1	2
19.	Science is a series of successively closer approximations to the truth.	1	2
20.	A scientist is often interested in finding relationships of the type, "when A occurs, then B will also occur."	1	2
21.	Scientists write articles for professional journals describing their research.	1	2
22.	Scientists do not make assumptions.	1	2
23.	Nature is not permitted to disobey the laws of science.	1	2
24.	Once a statement becomes a law of science, it will not be changed.	1	2
25.	A theory in science may be modified in light of new evidence.	1	2

		Agree	Disagree
26.	An experiment is a set of conditions under which observations are made.	1	2
27.	Assumptions are not accepted until they are proven true.	1	2
28.	The knowledge of science is final.	1	2
29.	Scientists usually make observations of nature to answer specific questions.	1	2
30.	Experimentation is principally concerned with proving the laws of nature.	1	2

(Statements 31 - 36 refer to the following information.) The Bohr model of the atom is a description of the atom similar in form to the solar system. It has a central nucleus of protons and neutrons surrounded by electron orbits. Statements 31 - 36 are concerned with this model.

31.	The model pictures the atom as we actually know it to exist.	1	2
32.	The model is a convenient way of representing the atom to help us understand it.	1	2
33.	The model presents an effective way of showing the different colors of the atomic particles.	1	2
34.	Scientific models are man-made.	1	2
35.	The model is a scaled-up picture of what scientists have seen in their microscopes.	1	2
36.	The model of the atom may be modified.	1	2
37.	Scientists do not make errors in their conclusions if they act "scientifically."	1	2
38.	A characteristic of scientific research is the use of instruments as aids to the senses.	1	2
39.	Experiments are used to test hypotheses.	1	2
40.	"Sea water contains salt," is an example of a scientific hypothesis.	1	2
41.	Science must start with facts and end with facts no matter what theoretical structures it builds in between.	1	2
42.	An accurate description of a scientific observation is a waste of time.	1	2
43.	A control in an experiment is used to give a check on factors not involved in the specific problem being studied.	1	2
44.	The assumptions in science are based on opinion, not fact.	1	2
45.	A law of nature is a description of what actually takes place, not a prescription of what must happen.	1	2
46.	It is the task of science to form theories to explain observations.	1	2
47.	Two people looking at the same sunrise may see different things.	1	2
48.	If the results of an experiment do not agree with the previous answer, then the experiment is wrong.	1	2
49.	A law in science describes what nature must do.	1	2
50.	Hypotheses have more experimental support than theories.	1	2

		Agree	Disagree
51.	The main object of basic scientific research is the discovery of understanding rather than its practical application.	1	2
52.	A classification scheme, such as the periodic table of the elements, is based on common factors and differences noted in observations.	1	2
53.	Theories in science are often expressed as mathematical relationships.	1	2
54.	"We are going to have 36 snowfalls this winter" is an example of a scientific theory.	1	2
55.	The published results of scientists should be accepted without question.	1	2
56.	Collecting rocks is an example of scientific investigation.	1	2
57.	The point of an experiment is to set up a situation in which the control of variables is greater than it is in the ordinary course of events.	1	2
58.	A hypothesis is a simple guess or "hunch" that tries to explain several observations.	1	2
59.	Scientific models are exact duplications of reality.	1	2
60.	Scientific conclusions should be based on facts, not opinion.	1	2
61.	Classification schemes are inherent in the materials classified, rather than imposed on nature by the scientist.	1	2
62.	Induction is the process of generalizing the characteristics of a class from observations of all of its members.	1	2
63.	Scientists view events today as clues to events in the past.	1	2
64.	The majority of newly suggested theories are accepted by the scientific community.	1	2
65.	Investigation of the possibilities of creating life in the laboratory is an invasion of science into areas where it doesn't belong.	1	2

(Items 66 - 77 are related to the following statement.) Those people who carry on the practice of science assume that:

66.	some mysterious occurrences do not have causes.	1	2
67.	all effects in nature have causes.	1	2
68.	if events A and B occur at the same time, then one must be the cause of the other.	1	2
69.	matter is an idea, not reality.	1	2
70.	events in nature are the result of discoverable causes.	1	2
71.	if a change in factor A leads to a change in factor B, then factor A is a cause of factor B.	1	2
72.	time can be measured.	1	2
73.	space does not exist.	1	2
74.	the human mind is capable of understanding the events and materials of nature.	1	2
75.	some natural things will never be understood.	1	2
76.	time is not real.	1	2
77.	some problems are too complex ever to be explained.	1	2
78.	Classification schemes are a useful means of organizing observations.	1	2
79.	Theories and hypotheses are often the result of comparisons.	1	2
80.	A hypothesis may be wrong.	1	2

		Agree	Disagree
81.	All models used in science are somewhat defective.	1	2
82.	If a scientist fails to solve a problem, it is probably because he did not follow the "scientific method."	1	2
83.	Grouping observations is an important part of scientific work.	1	2
84.	The scientist knows that his experiment will be successful if he follows the steps of the scientific method.	1	2
85.	A scientific hypothesis is essentially the same thing as a scientific fact.	1	2
86.	One of the aims of science is to work towards more complex knowledge.	1	2
87.	A scientist should be skeptical of anything but his own work.	1	2
88.	"It's hot in this room," is a more precise observation than "It's 84 degrees Fahrenheit in this room."	1	2
89.	Deduction is the process of predicting particular occurrences from the general case.	1	2
90.	A scientist should attempt to disprove his own hypotheses.	1	2
91.	A measurement expressed as 12 inches is a statement of approximation.	1	2
92.	Scientists usually rely on outside authority for their conclusions.	1	2
93.	The use of measurement is more evident in the biological sciences than the physical sciences.	1	2
94.	Prediction is an important goal of scientific investigation.	1	2
95.	The formulation of a theory is a means of explaining facts.	1	2
96.	If a choice is to be made between two theories, the more complex is chosen.	1	2
97.	To question the accuracy of Newton's theory of gravity would be unscientific.	1	2
98.	A measurement of length expressed as 15 inches is a statement of exact truth.	1	2
99.	"All swans are white. Penelope is a swan. Therefore, Penelope is white," is an example of deductive reasoning.	1	2
100.	"All matter consists of molecules," is an example of a scientific theory.	1	2
101.	A scientist prefers simple explanations of phenomena.	1	2
102.	Some presently accepted theories were opposed by other scientists when first proposed.	1	2
103.	Since a measurement involves the use of numbers, it cannot be wrong.	1	2
104.	Scientists assume a real world exists outside of the mind.	1	2
105.	A value of a hypothesis is its suggestion of new experiments.	1	2
106.	Scientific knowledge is in the process of development.	1	2
107.	Scientific investigations must follow definite approved procedures.	1	2
108.	A thermometer is an example of a measuring device.	1	2
109.	Scientists assume nature is likely to change suddenly.	1	2
110.	A theory with ten supporting and two denying experiments is more likely to be accepted than a theory with four supporting and no denying experiments.	1	2

		Agree	Disagree
111.	The law of conservation of energy is an example of an unchanging truth.	1	2
112.	Some scientific discoveries are the result of "luck."	1	2
113.	Physics is an exact science because physicists are able to make measurements without error.	1	2
114.	When a scientist makes a prediction, he is assuming that nature is consistent.	1	2
115.	Hypotheses may arise from imagination.	1	2
116.	The statements of science represent the best approximations available at the time.	1	2
117.	The basic principle of science is that discoveries and research should have practical application.	1	2
118.	Knowledge expressed in terms of numbers indicates a lesser degree of understanding than that knowledge which is not expressed numerically.	1	2
119.	A scientist believes that an experiment performed today will produce the same results as the same experiment performed last week.	1	2
120.	Scientific knowledge is tentative.	1	2
121.	There is only one scientific method used by scientists.	1	2
122.	When confronted with a new problem, a scientist searches the literature to see what similar work has been done.	1	2
123.	A scientist assumes the same cause produces the same effect under the same conditions.	1	2
124.	Applying the scientific method to a problem will always produce the correct answer.	1	2
125.	Science is essentially statistical in nature and deals in terms of probabilities.	1	2
126.	Scientists assume a force due to gravitation is present on all bodies of the universe.	1	2
127.	Scientists believe occurrences in nature are predictable.	1	2
128.	Scientists use "trial and error" approaches to problems with success.	1	2
129.	The primary objective of science is to develop new and improved living conveniences.	1	2
130.	Scientist A used one procedure to solve problem X, and scientist B used a different procedure to solve problem X. Both scientists solved the problem. This is impossible.	1	2
131.	A scientist is more likely to accept a theory on the basis of his personal ideas than on the experimental evidence available.	1	2
132.	It is important to express the "degree of estimate" in the findings of science.	1	2
133.	A scientist may be looking for the answer to one problem and find the answer to another.	1	2
134.	Experiments should be repeated, if possible.	1	2
135.	There are many methods of solving scientific problems.	1	2

SCIENCE PROCESS INVENTORY

Scoring Key

1-A	36-A	71-A	106-A
2-A	37-D	72-A	107-D
3-A	38-A	73-D	108-A
4-D	39-A	74-A	109-D
5-A	40-D	75-D	110-D
6-A	41-A	76-D	111-D
7-D	42-D	77-D	112-A
8-A	43-A	78-A	113-D
9-A	44-D	79-A	114-A
10-A	45-A	80-A	115-A
11-D	46-A	81-A	116-A
12-A	47-A	82-D	117-D
13-A	48-D	83-A	118-D
14-D	49-D	84-D	119-A
15-D	50-D	85-D	120-A
16-D	51-A	86-D	121-D
17-A	52-A	87-D	122-A
18-A	53-A	88-D	123-A
19-A	54-D	89-A	124-D
20-A	55-D	90-A	125-A
21-A	56-D	91-A	126-A
22-D	57-A	92-D	127-A
23-D	58-A	93-D	128-A
24-D	59-D	94-A	129-D
25-A	60-A	95-A	130-D
26-A	61-D	96-D	131-D
27-D	62-D	97-D	132-A
28-D	63-A	98-D	133-A
29-A	64-D	99-A	134-A
30-D	65-D	100-A	135-A
31-D	66-D	101-A	
32-A	67-A	102-A	
33-D	68-D	103-D	
34-A	69-D	104-A	
35-D	70-A	105-A	

APPENDIX B

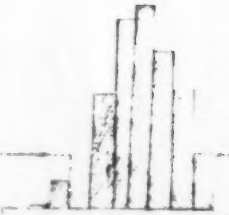
The 13 Hypothesized SPI Subscales

NOTE: The correlations in these tables is the point biserial correlation. The column titled "Bates" is the correlation between the item and the subscale. The column titled "Welch" is the correlation between the item and the total score on SPI (form B).

SPI (Form D) SUBSCALE SCORES

Subscale #1 - Universe: Orderly and Understandable

# Items	N	Mean	Std Dev	Std error	KR Rel
10	435	6.93	1.66	1.356	0.333



Grd/Pd	Va.	Item	SPI #	Description	Difficulty Peters	Difficulty Welch	Correlation Peters	Correlation Welch
25/1	12	1	12	Scientists assume there is order in the universe. (A)	.83	.91	.32	.55
76/1	13	2	63	Scientists view events today as clues to events in the past. (A)	.78	.81	.25	.32
19/2	9	3	74	Those people who carry on the practice of science assume that: the human mind is capable of understanding the events and materials of nature. (A)	.75	.70	.44	.15
20/2	10	4	75	Those people who carry on the practice of science assume that: some natural things will never be understood. (D)	.43	.78	.56	.18
22/2	11	5	77	Those people who carry on the practice of science assume that: some problems are too complex ever to be explained. (D)	.65	.60	.43	.40
52/2	14	6	109	Scientists assume nature is likely to change suddenly. (D)	.57	.76	.32	.34
59/2	15	7	114	When a scientist makes a prediction he is assuming that nature is consistent. (A)	.85	.75	.32	.33
64/2	16	8	119	A scientist believes that an experiment performed today will produce the same results as the same experiment performed last week. (A)	.49	.40	.46	.35
71/2	17	9	126	Scientists assume a force due to gravitation is present on all bodies of the universe. (A)	.80	.72	.27	.43
72/2	18	10	127	Scientists believe occurences in nature are predictable. (A)	.78	.88	.36	.45

SPI (Form D) SUBSCALE SEARCH

Subscale 2--Assumptions of Science

# Items	N	Mean	Std Dev	Std error	KR Rel
8	435	6.26	1.15	1.028	.206

Scr/Cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
30/1	1	1	17	Assumptions in science are based on past experience. (A)	.79	.83	.41	.37
35/1	2	2	22	Scientists do not make assumptions. (D)	.8[illegible]	.93	.42	.44
40/1	3	3	27	Assumptions are not accepted until they are proven true. (D)	.32	.17	.47	-.04
14/2	4	4	69	Those people who carry on the practice of science assume that: matter is an idea not reality. (D)	.92	.81	.35	.45
17/2	5	5	72	Those people who carry on the practice of science assume that: time can be measured. (A)	.79	.81	.38	.25
18/2	7	6	73	Those people who carry on the practice of science assume that: space does not exist. (D)	.95	.92	.31	-.13
21/2	6	7	76	Those people who carry on the practice of science assume that: time is not real. (D)	.84	.88	.42	.05
49/2	8	8	104	Scientists assume a real world exists outside of the mind. (A)	.82	.78	.36	.18

SPI (Form D) SUBSCALE SEARCH

Dates 73 74

Subscale 3--Causality

# Items	N	Mean	Std Dev	Std error	KR Rel
7	435	5.78	1.13	.949	.291

33/1	19	1	20	A scientist is often interested in finding	Difficulty		Correlation	
col. cd	var	item	SPI #	Description	Bates	Welch	Bates[1]	Welch[2]
33/1	19	1	20	A scientist is often interested in finding relationships of the type, "when A occurs, then B will also occur". (A)	.86	.89	.32	.63
79/1	20	2	66	Those people who carry on the practice of science assume that: some mysterious occurrences do not have causes. (D)	.90	.85	.50	.52
80/1	21	3	67	Those people who carry on the practice of science assume that: all effects in nature have causes. (A)	.94	.91	.42	.47
13/2	22	4	68	Those people who carry on the practice of science assume that: if events A and B occur at the same time, then one must be the cause of the other. (D)	.80	.65	.43	.28
15/2	23	5	70	Those people who carry on the practice of science assume that: events in nature are the result of discoverable causes. (A)	.73	.83	.55	.33
16/2	24	6	71	Those people who carry on the practice of science assume that: if a change in factor A leads to a change in factor B, then factor A is a cause of factor B. (A)	.69	.76	.42	.12
68/2	25	7	123	A scientist assumes the same cause produces the same effect under the same conditions. (A)	.86	.81	.46	.49

Subscale 4--Science is Tentative

# Items	N	Mean	Std Dev	Std error	KR Rel
15	435	12.64	1.47	1.256	0.267

Col/rd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation[1] Bates	Correlation[2] Welch
16/1	54	1	3	Scientists have differences of opinion about scientific matters. (A)	.89	.97	.32	.58
24/1	56	2	11	If a researcher accurately reports his experimental procedures, other researchers will accept the experimental conclusions without question. (D)	.91	.89	.29	.04
38/1	86	3	25	A theory in science may be modified in light of new evidence. (A) ?(Put in scale 11-Theories)?	.98	.91	.13	.64
41/1	87	4	28	The knowledge of science is final. (D)	.96	.89	.26	.52
68/1	124	5	55	The published results of scientists should be accepted without question. (D)	.95	.85	.29	.63
32/2	125	6	87	A scientist should be skeptical of anything but his own work. (D)	.85	.84	.21	.53
35/2	130	7	90	A scientist should attempt to disprove his own hypotheses. (A)	.77	.74	.43	.22
41/2	134	8	96	If a choice is to be made between two theories, the more complex is chosen. (D)	.92	.88	.27	?
42/2	127	9	97	To question the accuracy of Newton's theory of gravity would be unscientific. (D)	.92	.74	.30	.40
46/2	135	10	101	A scientist prefers simple explanations of phenomena. (A)	.57	.51	.36	?

continued on next page

Subscale 4 (continued)

# Items	N	Mean	Std Dev	Std error	KR Rel

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
47/2	128	11	102	Some presently accepted theories were opposed by other scientists when first proposed. (A)	.93	.94	.21	.51
51/2	88	12	106	Scientific knowledge is in the process of development. (A)	.93	.68	.33	?
56/2	89	13	111	The law of conservation of energy is an example of an unchanging truth. (D)	.39	.41	.30	?
61/2	90	14	116	The statements of science represent the best approximations available at the time. (A)	.91	.86	.34	?
65/2	91	15	120	Scientific knowledge is tentative. (A)	.76	.72	.43	?

SPI (Form D) SUBSCALE SEARCH

Subscale 5 -- Scientific Knowledge-Public and Objective

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	7.32	1.22	1.060	0.248

Rd/col	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
19/1	55	1	6	A scientist should make his findings available to the scientific community for independent confirmation. (A)	.86	.79	.42	.39
28/1	119	2	15	A scientist wishes to make prejudiced observations of nature. (D)	.90	.85	.34	.51
29/1	57	3	16	Scientists should be unwilling to share their findings with other scientists. (D)	.88	.91	.36	.42
34/1	58	4	21	Scientists write articles for professional journals describing their research. (A)	.88	.95	.41	.22
54/1	122	5	41	Science must start with facts and end with facts no matter what theoretical structures it builds in between. (A)	.49	.62	.40	-.22
57/1	123	6	44	The assumptions in science are based on opinion, not fact. (D)	.62	.64	.54	.13
73/1	120	7	60	Scientific conclusions should be based on facts, not opinion. (A)	.94	.93	.34	.30
67/2	59	8	122	When confronted with a new problem, a scientist searches the literature to see what similar work has been done. (A)	.95	.91	.20	.51
76/2	121	9	131	A scientist is more likely to accept a theory on the basis of his personal ideas than on the experimental evidence available. (D)	.80	.69	.37	.35

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

page 1/2

Subscale 6--Scientific Methods

# Items	N	Mean	Std Dev	Std error	KR Rel
12	435	10.54	1.31	1.046	0.360

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
14/1	33	1	1	Surprising or unexpected observations have played an important role in the advance of science. (A)	.96	.94	.25	.40
50/1	81	2	37	Scientists do not make errors in their conclusions if they act "scientifically". (D)	.94	.91	.37	.41
27/2	73	3	82	If a scientist fails to solve a problem, it is probably because he did not follow the "scientific method". (D)	.92	.91	.36	.46
29/2	74	4	84	The scientist knows that his experiment will be successful if he follows the steps of the scientific method. (D)	.94	.85	.37	.54
52/2	75	5	107	Scientific investigations must follow definite approved procedures. (D)	.57	.56	.51	.13
57/2	34	6	112	Some scientific discoveries are the result of "luck". (A)	.84	.83	.36	.31
66/2	76	7	121	There is only one scientific method used by scientists. (D)	.83	.91	.41	.42
69/2	77	8	124	Applying the scientific method to a problem will always produce the correct answer. (D)	.95	.94	.37	.80
73/2	78	9	128	Scientists use "trial and error" approaches to problems with success (A)	.81	.81	.37	.23
75/2	79	10	130	Scientist A used one procedure to solve problem X, and scientist B used a different procedure to solve problem X. Both scientists solved the problem. This is impossible. (D)	.89	.29	.87	.48

continue to next page

Subscale 6 (continued)

# Items	N	Mean	Std Dev	Std error	KR Rel

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
78/2	35	11	133	A scientist may be looking for the answer to one problem and find the answer to another. (A)	.98	.97	.24	.62
80/2	80	12	135	There are many methods of solving scientific problems. (A)	.91	.92	.34	.33

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 7--Experimentation

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	7.43	1.08	1.019	0.116

Pg/col/var	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
24/1 / 56	1	11	If a researcher accurately reports his experimental procedures, other researchers will accept the experimental conclusions without question. (D)	.91	.89	.32	.04
39/1 / 48	2	26	An experiment is a set of conditions under which observations are made. (A)	.97	.93	.19	.69
43/1 / 49	3	30	Experimentation is principally concerned with proving the laws of nature. (D)	.53	.56	.50	.21
51/1 / 30	4	38	A characteristic of scientific research is the use of instruments as aids to the senses. (A)	.94	.89	.29	.48
52/1 / 50	5	39	Experiments are used to test hypotheses. (A)	.94	.92	.31	.46
56/1 / 51	6	43	A control in an experiment is used to give a check on factors not involved in the specific problem being studied. (A)	.65	.52	.45	-.04
61/1 / 52	7	48	If the results of an experiment do not agree with the previous answer, then the experiment is wrong. (D)	.93	.90	.30	.49
70/1 / 53	8	57	The point of an experiment is to set up a situation in which the control of variables is greater than it is in the ordinary course of events. (A)	.61	.63	.48	.16
79/2 / 131	9	134	Experiments should be repeated, if possible. (A)	.95	.95	.20	.94

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 8--Measurement

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	7.91	1.20	0.903	0.431

Old/var	New/var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
33/2	36	1	88	"It's hot in this room", is a more precise observation than "It's 84 degrees Fahrenheit in this room". (D)	.91	.93	.27	.53
36/2	82	2	91	A measurement expressed as 12 inches is a statement of approximation. (A)	.67	.77	.64	?
38/2	37	3	93	The use of measurement is more evident in the biological sciences than the physical sciences. (D)	.93	.88	.33	.46
43/2	38	4	98	A measurement of length expressed as 15 inches is a statement of exact truth. (D)	.79	.66	.64	.37
48/2	39	5	103	Since a measurement involves the use of numbers, it cannot be wrong. (D)	.96	.89	.30	.58
53/2	40	6	108	A thermometer is an example of a measuring device. (A)	.98	.96	.11	.46
58/2	41	7	113	Physics is an exact science because physicists are able to make measurements without error. (D)	.93	.95	.48	.45
63/2	42	8	118	Knowledge expressed in terms of numbers indicates a lesser degree of understanding than that knowledge which is not expressed numerically. (D)	.86	.70	.41	.47
77/2	84	9	132	It is important to express the "degree of estimate" in the findings of science. (A)	.90	.88	.35	?

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 9--Observation

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	8.11	0.90	0.824	0.166

Key	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
15/1	31	1	2	The work of a scientist includes keeping a record of observations. (A)	.99	.98	.10	.49
17/1	118	2	4	Careful observation is less important in modern science since the development of new instruments like the electron microscope. (D)	.98	.93	.23	.47
18/1	28	3	5	The observations a person makes are influenced by his past experience. (A)	.63	.81	.62	.31
28/1	119	4	15	A scientist wishes to make prejudiced observations of nature. (D)	.90	.85	.37	.51
42/1	27	5	29	Scientists usually make observations of nature to answer specific questions. (A)	.81	.64	.43	.08
51/1	30	6	38	A characteristic of scientific research is the use of instruments as aids to the senses. (A)	.94	.89	.35	.48
55/1	32	7	42	An accurate description of a scientific observation is a waste of time. (D)	.94	.96	.31	.53
60/1	29	8	47	Two people looking at the same sunrise may see different things. (A)	.93	.95	.38	.29
28/2	47	9	83	Grouping observations is an important part of scientific work. (A)	.98	.91	.26	.18

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 10 -- Hypotheses

# Items	N	Mean	Std Dev	Std error	KR Rel
7	435	5.29	1.23	1.045	0.281

Seq/Grd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
53/1	61	1	40	"Sea water contains salt", is an example of a scientific hypothesis. (D)	.53	.62	.37	.24
63/1	94	2	50	Hypotheses have more experimental support than theories. (D)	.64	.65	.52	.27
71/1	62	3	58	A hypothesis is a simple guess or "hunch" that tries to explain several observations. (A)	.70	.77	.55	.16
25/2	63	4	80	A hypothesis may be wrong. (A)	.95	.95	.32	.42
30/2	64	5	85	A scientific hypothesis is essentially the same thing as a scientific fact. (D)	.90	.93	.46	.26
50/2	65	6	105	A value of a hypothesis is its suggestion of new experiments. (A)	.87	.82	.34	.38
60/2	66	7	115	Hypotheses may arise from imagination. (A)	.71	.69	.48	.09

SPI (Form D) SUBSCALE SEARCH

Subscale 11 -- Theories

# Items	N	Mean	Std Dev	Std error	KR Rel
13	435	10.77	1.46	1.284	0.229

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
20/1	92	1	7	Theories are usually so well established, they do not require experimental testing. (D)	.96	.89	.14	.38
21/1	69	2	8	The essential test of a scientific theory is its use in predicting future events. (A)	.52	.72	.39	.15
31/1	93	3	18	Theories suggest new relationships among facts. (A)	.92	.93	.32	.22
38/1	86	4	25	A theory in science may be modified in light of new evidence. (A)	.98	.91	.14	.64
59/1	114	5	46	It is the task of science to form theories to explain observations. (A)	.85	.88	.35	.45
66/1	95	6	53	Theories in science are often expressed as mathematical relationships. (A)	.84	.93	.38	.44
67/1	96	7	54	"We are going to have 36 snowfalls this winter" is an example of a scientific theory. (D)	.78	.70	.28	.13
77/1	97	8	64	The majority of newly suggested theories are accepted by the scientific community. (D)	.74	.70	.28	.31
24/2	72	9	79	Theories and hypotheses are often the result of comparisons. (A)	.89	.85	.29	.38
39/2	70	10	94	Prediction is an important goal of scientific investigation. (A)	.83	.77	.39	.14

Continued on next page.

SPI (Form D) SUBSCALE SEARCH

Dates 1973-74

Subscale 11 (continued)

# Items	N	Mean	Std Dev	Std error	KR Rel

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
40/2	71	11	95	The formulation of a theory is a means of explaining facts. (A)	.87	.81	.39	.30
45/2	98	12	100	"All matter consists of molecules", is an example of a scientific theory.(A)	.80	.79	.37	.17
55/2	99	13	110	A theory with ten supporting and two denying experiments is more likely to be accepted than a theory with four supporting and no denying experiments. (D)	.80	.74	.27	.49

SPI (Form D) SUBSCALE SEARCH

Subscal. 12 -- Models

# Items	N	Mean	Std Dev	Std error	KR Rel
8	435	6.57	1.37	0.969	0.503

	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
				The Bohr model of the atom is a description of the atom similar in form to the solar system. It has a central nucleus of protons and neutrons surrounded by electron orbits. Statements 31-36 are concerned with this model.				
44/1	100	1	31	The model pictures the atom as we actually know it to exist. (D)	.60	.44	.60	.49
45/1	101	2	32	The model is a convenient way of representing the atom to help us understand it. (A)	.97	.94	.17	.19
46/1	102	3	[illegible]	The model presents an effective way of showing the different colors of the atomic particles. (D)	.83	.85	.47	.40
47/1	103	4	34	Scientific models are man-made. (A)	.90	.93	.36	.41
48/1	104	5	35	The model is a scaled-up picture of what scientists have seen in their microscopes. (D)	.67	.58	.64	.53
49/1	105	6	36	The model of the atom may be modified. (A)	.87	.83	.48	.55
74/1	106	7	59	Scientific models are exact duplications of reality. (D)	.92	.31	.49	-.11*
26/2	107	8	81	All models used in science are somewhat defective. (A)	.81	.68	.45	.10*

SPI (Form D) SUBSCALE SEARCH

Subscale 13 -- Laws

# Items	N	Mean	Std Dev	Std error	KR Rel
6	435	4.54	1.09	0.944	0.246

col/rd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
26/1	108	1	13	A law of nature, such as Ohm's Law, is a statement that describes what has been observed. (A)	.79	.91	.46	.20
27/1	109	2	14	Although a scientific hypothesis may have to be changed on the basis of new data, a physical law is permanent. (D)	.41	.50	.51	.22
36/1	110	3	23	Nature is not permitted to disobey the laws of science. (D)	.90	.95	.47	.62
37/1	111	4	24	Once a statement becomes a law of science, it will not be changed. (D)	.89	.86	.42	.22
58/1	112	5	45	A law of nature is a description of what actually takes place, not a prescription of what must happen. (A)	.81	.80	.35	.33
62/1	113	6	49	A law in science describes what nature must do. (D)	.74	.55	.55	.16

APPENDIX A

Science Process Inventory

Form D (Revised 1966)

Wayne W. Welch
University of Wisconsin

SCIENCE PROCESS INVENTORY

Scoring Key

1-A	36-A	71-A	106-A
2-A	37-D	72-A	107-D
3-A	38-A	73-D	108-A
4-D	39-A	74-A	109-D
5-A	40-D	75-D	110-D
6-A	41-A	76-D	111-D
7-D	42-D	77-D	112-A
8-A	43-A	78-A	113-D
9-A	44-D	79-A	114-A
10-A	45-A	80-A	115-A
11-D	46-A	81-A	116-A
12-A	47-A	82-D	117-D
13-A	48-D	83-A	118-D
14-D	49-D	84-D	119-A
15-D	50-D	85-D	120-A
16-D	51-A	86-D	121-D
17-A	52-A	87-D	122-A
18-A	53-A	88-D	123-A
19-A	54-D	89-A	124-D
20-A	55-D	90-A	125-A
21-A	56-D	91-A	126-A
22-D	57-A	92-D	127-A
23-D	58-A	93-D	128-A
24-D	59-D	94-A	129-D
25-A	60-A	95-A	130-D
26-A	61-D	96-D	131-D
27-D	62-D	97-D	132-A
28-D	63-A	98-D	133-A
29-A	64-D	99-A	134-A
30-D	65-D	100-A	135-A
31-D	66-D	101-A	
32-A	67-A	102-A	
33-D	68-D	103-D	
34-A	69-D	104-A	
35-D	70-A	105-A	

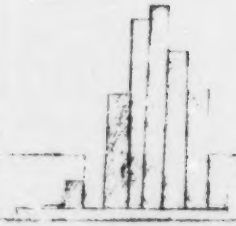
APPENDIX B

The 13 Hypothesized SPI Subscales

NOTE: The correlations in these tables is the point biserial correlation. The column titled "Bates" is the correlation between the item and the subscale. The column titled "Welch" is the correlation between the item and the total score on SPI (form B).

SPI (Form D) Subscale Stock

Subscale #1 - Universe: Orderly and Understandable



# Items	N	Mean	Std Dev	Std error	KR Rel
10	435	6.93	1.66	1.356	0.333

Std/Sel	Nex	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bate	Correlation Welch
25/1	12	1	12	Scientists assume there is order in the universe. (A)	.83	.91	.32	.55
76/1	13	2	63	Scientists view events today as clues to events in the past. (A)	.78	.81	.25	.32
19/2	9	3	74	Those people who carry on the practice of science assume that: the human mind is capable of understanding the events and materials of nature. (A)	.75	.70	.44	.15
20/2	10	4	75	Those people who carry on the practice of science assume that: some natural things will never be understood. (D)	.43	.78	.56	.18
22/2	11	5	77	Those people who carry on the practice of science assume that: some problems are too complex ever to be explained. (D)	.65	.60	.43	.40
52/2	14	6	109	Scientists assume nature is likely to change suddenly. (D)	.57	.76	.32	.34
59/2	15	7	114	When a scientist makes a prediction he is assuming that nature is consistent. (A)	.85	.75	.32	.33
64/2	16	8	119	A scientist believes that an experiment performed today will produce the same results as the same experiment performed last week. (A)	.49	.40	.46	.35
71/2	17	9	126	Scientists assume a force due to gravitation is present on all bodies of the universe. (A)	.80	.72	.27	.43
72/2	18	10	127	Scientists believe occurences in nature are predictable. (A)	.78	.88	.36	.45

SPI (Form D) SUBSCALE SEARCH

Subscale 2--Assumptions of Science

# Items	N	Mean	Std Dev	Std error	KR Rel
8	435	6.26	1.15	1.028	.206

Col/card	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
30/1	1	1	17	Assumptions in science are based on past experience. (A)	.79	.83	.41	.37
35/1	2	2	22	Scientists do not make assumptions. (D)	.85	.93	.42	.44
40/1	3	3	27	Assumptions are not accepted until they are proven true. (D)	.32	.17	.47	-.04
14/2	4	4	69	Those people who carry on the practice of science assume that: matter is an idea not reality. (D)	.92	.81	.35	.45
17/2	5	5	72	Those people who carry on the practice of science assume that: time can be measured. (A)	.79	.81	.38	.25
18/2	7	6	73	Those people who carry on the practice of science assume that: space does not exist. (D)	.95	.92	.31	-.13
21/2	6	7	76	Those people who carry on the practice of science assume that: time is not real. (D)	.84	.88	.42	.05
49/2	8	8	104	Scientists assume a real world exists outside of the mind. (A)	.82	.78	.36	.18

SPI (Form D) SUBSCALE SEARCH

Subscale 3--Causality

# Items	N	Mean	Std Dev	Std error	KR Rel
7	435	5.78	1.13	.949	.291

col/card	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation 1 Bates	Correlation 2 Welch
33/1	19	1	20	A scientist is often interested in finding relationships of the type, "when A occurs, then B will also occur". (A)	.86	.89	.32	.63
79/1	20	2	66	Those people who carry on the practice of science assume that: some mysterious occurrences do not have causes. (D)	.90	.85	.50	.52
80/1	21	3	67	Those people who carry on the practice of science assume that: all effects in nature have causes. (A)	.94	.91	.42	.47
13/2	22	4	68	Those people who carry on the practice of science assume that: if events A and B occur at the same time, then one must be the cause of the other. (D)	.80	.65	.43	.28
15/2	23	5	70	Those people who carry on the practice of science assume that: events in nature are the result of discoverable causes. (A)	.73	.83	.55	.33
16/2	24	6	71	Those people who carry on the practice of science assume that: if a change in factor A leads to a change in factor B, then factor A is a cause of factor B. (A)	.69	.76	.42	.12
68/2	25	7	123	A scientist assumes the same cause produces the same effect under the same conditions. (A)	.86	.81	.46	.49

page 1/2

Subscale 4--Science is Tentative

# Items	N	Mean	Std Dev	Std error	KR Rel
15	435	12.64	1.47	1.256	0.267

Col/l	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation[1] Bates	Correlation[2] Welch
16/1	54	1	3	Scientists have differences of opinion about scientific matters. (A)	.89	.97	.32	.58
24/1	56	2	11	If a researcher accurately reports his experimental procedures, other researchers will accept the experimental conclusions without question. (D)	.91	.89	.29	.04
38/1	86	3	25	A theory in science may be modified in light of new evidence. (A) ?(Put in scale 11-Theories)?	.98	.91	.13	.64
41/1	87	4	28	The knowledge of science is final. (D)	.96	.89	.26	.52
68/1	124	5	55	The published results of scientists should be accepted without question. (D)	.95	.85	.29	.63
32/2	125	6	87	A scientist should be skeptical of anything but his own work. (D)	.85	.84	.21	.53
35/2	130	7	90	A scientist should attempt to disprove his own hypotheses. (A)	.77	.74	.43	.22
41/2	134	8	96	If a choice is to be made between two theories, the more complex is chosen. (D)	.92	.88	.27	?
42/2	127	9	97	To question the accuracy of Newton's theory of gravity would be unscientific. (D)	.92	.74	.30	.40
46/2	135	10	101	A scientist prefers simple explanations of phenomena. (A)	.57	.51	.36	?

continued on next page

Subscale 4 (continued)

# Items	N	Mean	Std Dev	Std error	KR Rel

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
47/2	128	11	102	Some presently accepted theories were opposed by other scientists when first proposed. (A)	.93	.94	.21	.51
51/2	88	12	106	Scientific knowledge is in the process of development. (A)	.93	.68	.33	?
56/2	89	13	111	The law of conservation of energy is an example of an unchanging truth. (D)	.39	.41	.30	?
61/2	90	14	116	The statements of science represent the best approximations available at the time. (A)	.91	.86	.34	?
65/2	91	15	120	Scientific knowledge is tentative. (A)	.76	.72	.43	?

SPI (Form D) SUBSCALE SEARCH

Subscale 5 -- Scientific Knowledge-Public and Objective

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	7.32	1.22	1.060	0.248

Scl/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
19/1	55	1	6	A scientist should make his findings available to the scientific community for independent confirmation. (A)	.86	.79	.42	.39
28/1	119	2	15	A scientist wishes to make prejudiced observations of nature. (D)	.90	.85	.34	.51
29/1	57	3	16	Scientists should be unwilling to share their findings with other scientists. (D)	.88	.91	.36	.42
34/1	58	4	21	Scientists write articles for professional journals describing their research. (A)	.88	.95	.41	.22
54/1	122	5	41	Science must start with facts and end with facts no matter what theoretical structures it builds in between. (A)	.49	.62	.40	-.22
57/1	123	6	44	The assumptions in science are based on opinion, not fact. (D)	.62	.64	.54	.13
73/1	120	7	60	Scientific conclusions should be based on facts, not opinion. (A)	.94	.93	.34	.30
67/2	59	8	122	When confronted with a new problem, a scientist searches the literature to see what similar work has been done. (A)	.95	.91	.20	.51
76/2	121	9	131	A scientist is more likely to accept a theory on the basis of his personal ideas than on the experimental evidence available. (D)	.80	.69	.37	.35

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

page 1/2

Subscale 6--Scientific Methods

# Items	N	Mean	Std Dev	Std error	KR Rel
12	435	10.54	1.31	1.046	0.360

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
14/1	33	1	1	Surprising or unexpected observations have played an important role in the advance of science. (A)	.96	.94	.25	.40
50/1	81	2	37	Scientists do not make errors in their conclusions if they act "scientifically". (D)	.94	.91	.37	.41
27/2	73	3	82	If a scientist fails to solve a problem, it is probably because he did not follow the "scientific method". (D)	.92	.91	.36	.46
29/2	74	4	84	The scientist knows that his experiment will be successful if he follows the steps of the scientific method. (D)	.94	.85	.37	.54
52/2	75	5	107	Scientific investigations must follow definite approved procedures. (D)	.57	.56	.51	.13
57/2	34	6	112	Some scientific discoveries are the result of "luck". (A)	.84	.83	.36	.31
66/2	76	7	121	There is only one scientific method used by scientists. (D)	.83	.91	.41	.42
69/2	77	8	124	Applying the scientific method to a problem will always produce the correct answer. (D)	.95	.94	.37	.80
73/2	78	9	128	Scientists use "trial and error" approaches to problems with success (A)	.81	.81	.37	.23
75/2	79	10	130	Scientist A used one procedure to solve problem X, and scientist B used a different procedure to solve problem X. Both scientists solved the problem. This is impossible. (D)	.89	.29	.87	.48

continue to next page

SPI (Form D) SUBSCALE SEARCH

Subscale 6 (continued)

# Items	N	Mean	Std Dev	Std error	KR Rel

col/card	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
78/2	35	11	133	A scientist may be looking for the answer to one problem and find the answer to another. (A)	.98	.97	.24	.62
80/2	80	12	135	There are many methods of solving scientific problems. (A)	.91	.92	.34	.33

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 7--Experimentation

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	7.43	1.08	1.019	0.116

Booklet/var	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
24/1	56	1	11	If a researcher accurately reports his experimental procedures, other researchers will accept the experimental conclusions without question. (D)	.91	.89	.32	.04
39/1	48	2	26	An experiment is a set of conditions under which observations are made. (A)	.97	.93	.19	.69
43/1	49	3	30	Experimentation is principally concerned with proving the laws of nature. (D)	.53	.56	.50	.21
51/1	30	4	38	A characteristic of scientific research is the use of instruments as aids to the senses. (A)	.94	.89	.29	.48
52/1	50	5	39	Experiments are used to test hypotheses. (A)	.94	.92	.31	.46
56/1	51	6	43	A control in an experiment is used to give a check on factors not involved in the specific problem being studied. (A)	.65	.52	.45	-.04
61/1	52	7	48	If the results of an experiment do not agree with the previous answer, then the experiment is wrong. (D)	.93	.90	.30	.49
70/1	53	8	57	The point of an experiment is to set up a situation in which the control of variables is greater than it is in the ordinary course of events. (A)	.61	.63	.48	.16
79/2	131	9	134	Experiments should be repeated, if possible. (A)	.95	.95	.20	.94

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 8--Measurement

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	7.91	1.20	0.903	0.431

Test/Year	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
33/2	1	88	"It's hot in this room", is a more precise observation than "It's 84 degrees Fahrenheit in this room". (D)	.91	.93	.27	.53
36/2	2	91	A measurement expressed as 12 inches is a statement of approximation. (A)	.67	.77	.64	?
38/2	3	93	The use of measurement is more evident in the biological sciences than the physical sciences. (D)	.93	.88	.33	.46
43/2	4	98	A measurement of length expressed as 15 inches is a statement of exact truth. (D)	.79	.66	.64	.37
48/2	5	103	Since a measurement involves the use of numbers, it cannot be wrong. (D)	.96	.89	.30	.58
53/2	6	108	A thermometer is an example of a measuring device. (A)	.98	.96	.11	.46
58/2	7	113	Physics is an exact science because physicists are able to make measurements without error. (D)	.93	.95	.48	.45
63/2	8	118	Knowledge expressed in terms of numbers indicates a lesser degree of understanding than that knowledge which is not expressed numerically. (D)	.86	.70	.41	.47
77/2	9	132	It is important to express the "degree of estimate" in the findings of science. (A)	.90	.88	.35	?

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 9--Observation

# Items	N	Mean	Std Dev	Std error	KR Rel
9	435	8.11	0.90	0.824	0.166

Per	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
15/1	31	2	The work of a scientist includes keeping a record of observations. (A)	.99	.98	.10	.49
17/1	118	4	Careful observation is less important in modern science since the development of new instruments like the electron microscope. (D)	.98	.93	.23	.47
18/1	28	5	The observations a person makes are influenced by his past experience. (A)	.63	.81	.62	.31
28/1	119	15	A scientist wishes to make prejudiced observations of nature. (D)	.90	.85	.37	.51
42/1	27	29	Scientists usually make observations of nature to answer specific questions. (A)	.81	.64	.43	.08
51/1	30	38	A characteristic of scientific research is the use of instruments as aids to the senses. (A)	.94	.89	.35	.48
55/1	32	42	An accurate description of a scientific observation is a waste of time. (D)	.94	.96	.31	.53
60/1	29	47	Two people looking at the same sunrise may see different things. (A)	.93	.95	.38	.29
28/2	47	83	Grouping observations is an important part of scientific work. (A)	.98	.91	.26	.18

SPI (Form D) SUBSCALE SEARCH

Bates 1973-74

Subscale 10 -- Hypotheses

# Items	N	Mean	Std Dev	Std error	KR Rel
7	435	5.29	1.23	1.045	0.281

Card	Var	Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
53/1	61	1	40	"Sea water contains salt", is an example of a scientific hypothesis. (D)	.53	.62	.37	.24
63/1	94	2	50	Hypotheses have more experimental support than theories. (D)	.64	.65	.52	.27
71/1	62	3	58	A hypothesis is a simple guess or "hunch" that tries to explain several observations. (A)	.70	.77	.55	.16
25/2	63	4	80	A hypothesis may be wrong. (A)	.95	.95	.32	.42
30/2	64	5	85	A scientific hypothesis is essentially the same thing as a scientific fact. (D)	.90	.93	.46	.26
50/2	65	6	105	A value of a hypothesis is its suggestion of new experiments. (A)	.87	.82	.34	.38
60/2	66	7	115	Hypotheses may arise from imagination. (A)	.71	.69	.48	.09

SPI (Form D) SUBSCALE SEARCH

Subscale 11 -- Theories

# Items	N	Mean	Std Dev	Std error	KR Rel
13	435	10.77	1.46	1.284	0.229

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
20/1	92	1	7	Theories are usually so well established, they do not require experimental testing. (D)	.96	.89	.14	.38
21/1	69	2	8	The essential test of a scientific theory is its use in predicting future events. (A)	.52	.72	.39	.15
31/1	93	3	18	Theories suggest new relationships among facts. (A)	.92	.93	.32	.22
38/1	86	4	25	A theory in science may be modified in light of new evidence. (A)	.98	.91	.14	.64
59/1	114	5	46	It is the task of science to form theories to explain observations. (A)	.85	.88	.35	.45
66/1	95	6	53	Theories in science are often expressed as mathematical relationships. (A)	.84	.93	.38	.44
67/1	96	7	54	"We are going to have 36 snowfalls this winter" is an example of a scientific theory. (D)	.78	.70	.28	.13
77/1	97	8	64	The majority of newly suggested theories are accepted by the scientific community. (D)	.74	.70	.28	.31
24/2	72	9	79	Theories and hypotheses are often the result of comparisons. (A)	.89	.85	.29	.38
39/2	70	10	94	Prediction is an important goal of scientific investigation. (A)	.83	.77	.39	.14

Continued on next page.

Subscale 11 (continued)

# Items	N	Mean	Std Dev	Std error	KR Rel

col/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
40/2	71	11	95	The formulation of a theory is a means of explaining facts. (A)	.87	.81	.39	.30
45/2	98	12	100	"All matter consists of molecules", is an example of a scientific theory. (A)	.80	.79	.37	.17
55/2	99	13	110	A theory with ten supporting and two denying experiments is more likely to be accepted than a theory with four supporting and no denying experiments. (D)	.80	.74	.27	.49

SPI (Form D) SUBSCALE SEARCH

Subscale 12 -- Models

# Items	N	Mean	Std Dev	Std error	KR Rel
8	435	6.57	1.37	0.969	0.503

Item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
		The Bohr model of the atom is a description of the atom similar in form to the solar system. It has a central nucleus of protons and neutrons surrounded by electron orbits. Statements 31-36 are concerned with this model.				
1	31	The model pictures the atom as we actually know it to exist. (D)	.60	.44	.60	.49
2	32	The model is a convenient way of representing the atom to help us understand it. (A)	.97	.94	.17	.19
3	33	The model presents an effective way of showing the different colors of the atomic particles. (D)	.83	.85	.47	.40
4	34	Scientific models are man-made. (A)	.90	.93	.36	.41
5	35	The model is a scaled-up picture of what scientists have seen in their microscopes. (D)	.67	.58	.64	.53
6	36	The model of the atom may be modified. (A)	.87	.83	.48	.55
7	59	Scientific models are exact duplications of reality. (D)	.92	.31	.49	-.11*
8	81	All models used in science are somewhat defective. (A)	.81	.68	.45	.10*

SPI (Form D) SUBSCALE SEARCH

Subscale 13 -- Laws

# Items	N	Mean	Std Dev	Std error	KR Rel
6	435	4.54	1.09	0.944	0.246

.cpi/cd	var	item	SPI #	Description	Difficulty Bates	Difficulty Welch	Correlation Bates	Correlation Welch
26/1	108	1	13	A law of nature, such as Ohm's Law, is a statement that describes what has been observed. (A)	.79	.91	.46	.20
27/1	109	2	14	Although a scientific hypothesis may have to be changed on the basis of new data, a physical law is permanent. (D)	.41	.50	.51	.22
36/1	110	3	23	Nature is not permitted to disobey the laws of science. (D)	.90	.95	.47	.62
37/1	111	4	24	Once a statement becomes a law of science, it will not be changed. (D)	.89	.86	.42	.22
58/1	112	5	45	A law of nature is a description of what actually takes place, not a prescription of what must happen. (A)	.81	.80	.35	.33
62/1	113	6	49	A law in science describes what nature must do. (D)	.74	.55	.55	.16